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Advanced Aircraft Analysis User's Manual Version 3.6

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Advanced Aircraft Analysis User's Manual
2014

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PART I

Software System Organization

This part describes the general functions of the mouse and program options used in the software and gives an overview of the different types of files used.

---

1 Introduction

The software provides a powerful framework to support the iterative and non-unique process of aircraft preliminary design. It allows students and preliminary design engineers to rapidly evolve a preliminary aircraft configuration from early weight sizing through open-loop and closed-loop dynamic stability and sensitivity analysis, while working within regulatory and cost constraints.

The software is written for the Microsoft Windows graphical interfaces. This allows the user to take full advantage of the interface. It is recommended that it be run as a full screen program with a display resolution of at least 1024 x 768 or higher. It will run with any display resolution, but scrolling may become necessary for display resolutions less than 1024 x 768.

The software consists of ten application modules, a detailed help system, environment setup and project handling tools. Chapter 2 describes the structure of the program. Chapters 3 and 4 describe and explain the various tools used in the program. Chapter 5 discusses the project handling methods and capabilities of the software. Chapter 6 describes the online help system in the software.

All information contained in this manual is also contained in the software help system. The help

system can be accessed at any time from within the program by selecting the Help button at the bottom of the main window, by selecting an option in the Help menu at the top of the main window, by selecting the Theory button in the input/output window, or by pressing F1 on the keyboard. The help system can also be accessed by selecting the User's Manual icon in the software program group in Windows.

2 Structure of the Software

The software uses windows, toolbars and dialog boxes to communicate with the user. This chapter describes the structural elements of the software, their purpose and their functionality. The following elements of the software are described in this chapter:

2.1 Windows and command bars

2.2 Toolbars

2.3 Menu bar

2.1 Windows and Command Bars

The software is started by selecting the program icon in the Airplane Design and Analysis program group in Windows. When the program is started, the main window (Figure 2.1) is displayed. This window is open as long as the program is running. The main window contains a Windows menu bar at the top, the main menu of application modules, the software toolbars and the status bar. The status bar is located at the bottom of the main window and contains the company name and project name as specified by the user, and the current date and time. When an element of the status bar is double clicked with the mouse button, a dialog box appears to change the content or format of that element (see Section 2.2).

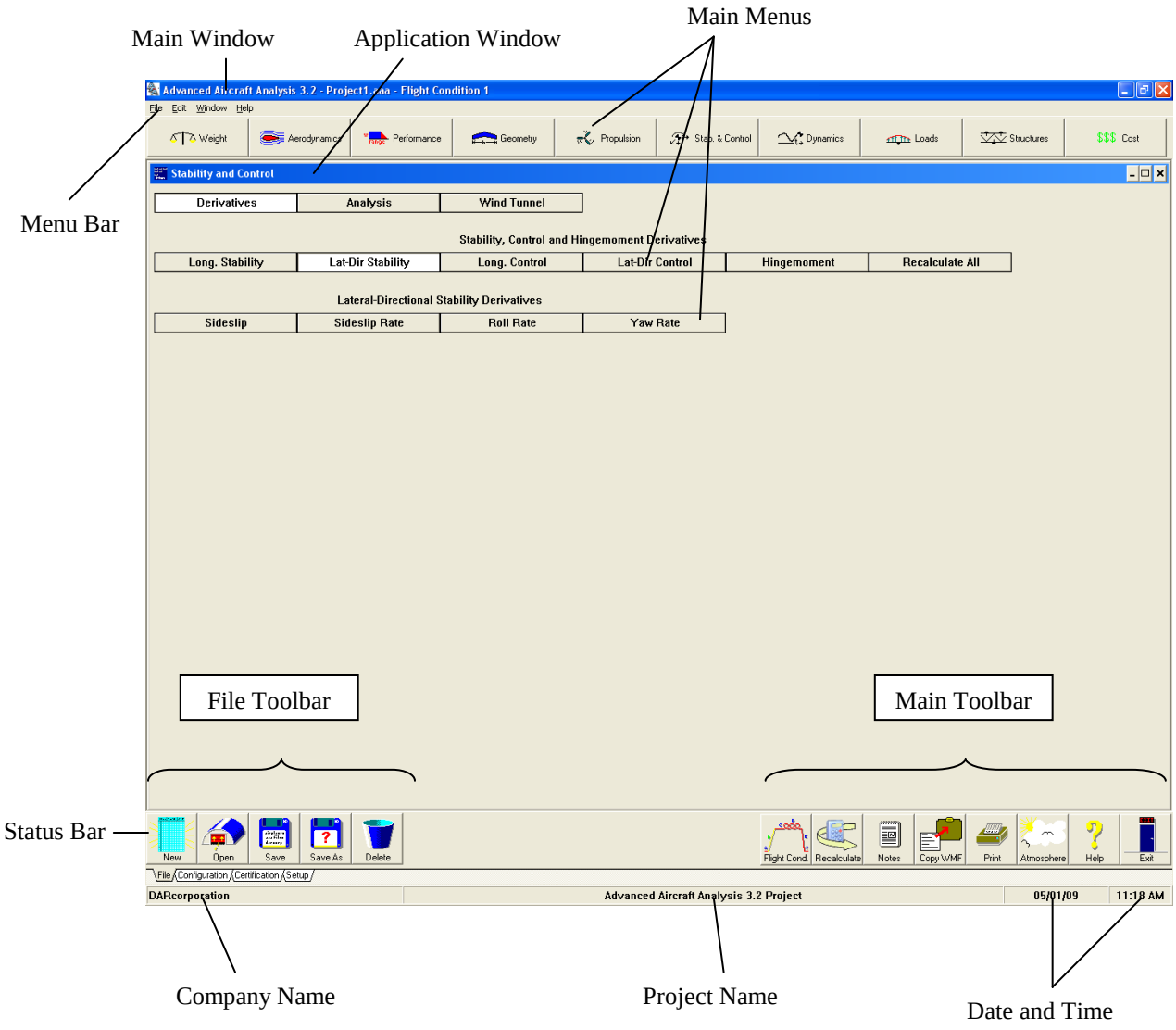


Figure 2.1 The Main Window

Three types of windows can be contained within the main window. There are application windows, input/output windows and plot windows. Application windows, input/output windows and plot windows are child windows and are always displayed within the main window. Descriptions of each of these window types and their components are presented in the following subsections:

2.1.1 Application windows

2.1.2 Input/Output windows

2.1.3 Input/Output window command bar

2.1.4 Plot windows

2.1.5 Plot window command bar

2.1.1 Application Windows

When one of the application buttons at the top of the main window is selected, the corresponding application window is displayed (see Figure 2.1). The application window contains menu button selections that allow the user to select a calculation to be performed. The software uses a flow chart method for the user interface as shown in Figure 2.1. This allows the user to see the path selected in reaching a certain location.

The software consists of various calculation modules that can be accessed through the application windows. Table 2.1 presents the application buttons in the main window and the calculation modules accessed by that application module.

Table 2.1 Application Modules of the Program

Application Button	**Calculation Modules**
Weight	• Class I take-off weight and fuel calculation • Class I and Class II weight & balance analysis and center of gravity calculation for current loading
Aerodynamics	• Class I wing and high lift devices design • Class I lifting surface and airplane lift calculation • Class I and Class II drag polar calculation • Lift, drag and moment distributions over a lifting surface • Airplane aerodynamic center calculation • Power effects on airplane lift and pitching moment • Ground effects of airplane lift and pitching moment • Dynamic Pressure Ratio
Performance	• Class I performance sizing • Class II performance analysis

Table 2.1 Continued

Application Button	Calculation Modules
Geometry	• Class I wing, fuselage and empennage layout • Aero-Pack Interface • Lateral tip-over analysis • Scale
Propulsion	• Class I installed thrust/power calculation • Inlet/Nozzle sizing
Stab. & Control	• Longitudinal and lateral-directional stability and control derivatives, including thrust/power • Control surface and trim tab hinge moment derivatives • Class I stability & control empennage sizing • Class II longitudinal and lateral-directional trim, including stick force and pedal force calculations
Dynamics	• Open loop dynamics analysis • Automatic control system analysis
Loads	• Velocity-Load Factor (V-n) diagram generation • Structural component internal load estimation
Structures	• Material property tables • Class I component structural sizing
Cost	• Airplane program cost estimation

Clicking on the appropriate buttons in the application window activates each module. When the menu buttons leading to a calculation module have been selected, the input/output window for that calculation module is opened.

2.1.2 Input/Output Windows

The input/output window opens after selecting the type of calculation to be performed. The input/output window contains numeric data necessary to perform a calculation. For some

calculations, information about the airplane configuration and airplane certification type are required so that the correct calculation method can be used. Before the input/output window is displayed, the program will display a dialog box allowing the user to specify configuration choices. For example, the program will ask the user to define empennage surfaces before the input/output window for longitudinal stability calculations is displayed.

Input/output windows contain a command bar at the top of the window, an input group and an output group (See Figure 2.2). The command bar contains a menu of buttons, one for each command available to the input/output window. The input/output window command bar is described in Subsection 2.1.3.

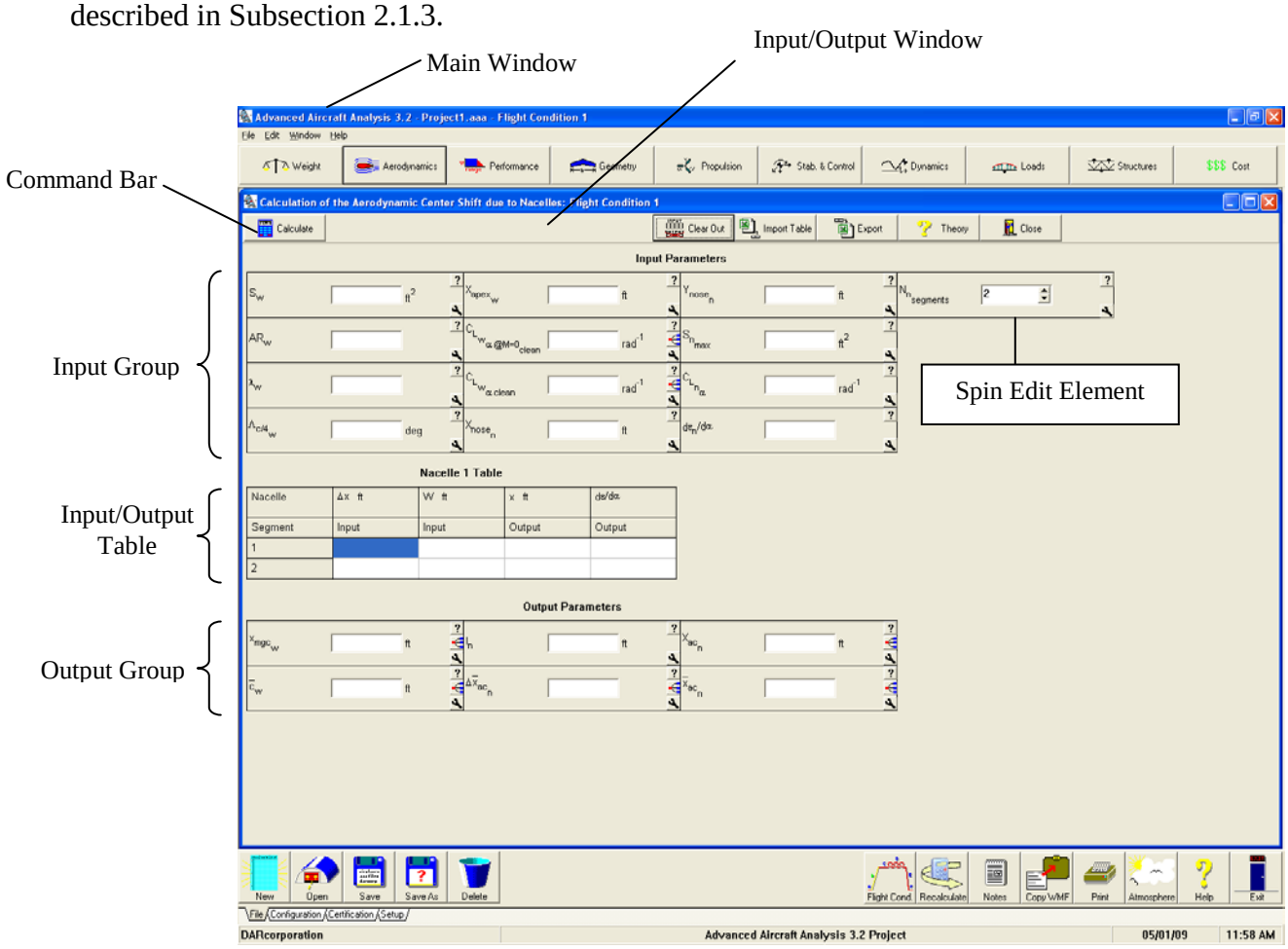


Figure 2.2 Input/Output Window

Input/output windows contain one or more input/output elements. Figure 2.3 shows an input/output element. The input/output element contains the following:

- Variable Symbol
- Edit Box for keyboard input
- Unit (SI or British)
- Info ? button
- Go To button
- Work Pad button

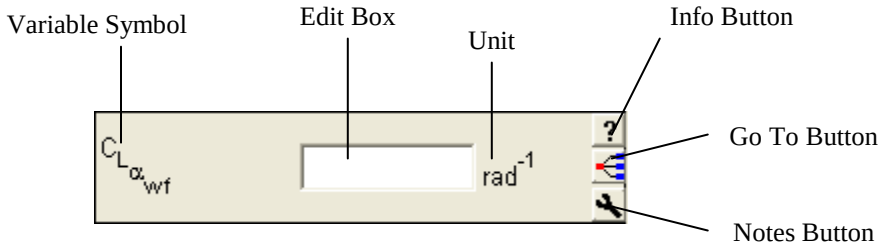


Figure 2.3 Input/Output Elements

When the cursor is positioned over an input/output element, a brief description of the parameter is displayed. When the cursor is located over the edit box of the input/output element, it appears as a vertical bar. When the edit box is selected with the left mouse button, a vertical insertion bar appears in the edit box, and the keyboard can be used to type numeric input. When the cursor is positioned outside the edit box, it appears as a small calculator. When the left mouse button is clicked while the cursor appears as a calculator, the program calculator is opened (see Section 3.2).

When the **Info** button is clicked, an information window is displayed for that variable. The information window contains a definition of the variable with graphics and suggested values when available (see Section 6.2).

Figure 2.4 shows the Notes window. When the **Work Pad** button is clicked, this window is displayed and allows the user to type notes about that variable. These notes are specific to that variable and will be saved with the project. Notes may also be designated one of six colors to identify certain stages of the design process. This is done by simply clicking on the desired color

in the “Set Current Note Color” box of the Work Pad Window. If a color is not selected from this portion of the Work Pad Window, the default color will be used with that particular note. If notes have been entered for a variable, the **Work Pad** button will change colors to the default notes color. The default notes color can be set or changed in the Program Options window (See Figure 2.30). The Work Pad Window also has options to allow the user to lock the value of the variable so that it does not get recalculated, export the value to an ASCII text file, or select whether or not the variable is flight condition dependent. The “Default Unit” box in the Work Pad Window allows the user to change the units for the variable associated with the window without changing the default units for the entire project. The number of decimals can be increased or decreased using the “Number of Decimals” box.

The **Go To** button appears next to parameters which have been calculated by AAA in another module. Selecting the **Go To** button will display the module in which the corresponding parameter was calculated. This allows the user to see what variables were used in producing the parameter, and confirm its validity. Clicking on the **Go To** button a second time will return the user to the previous module.

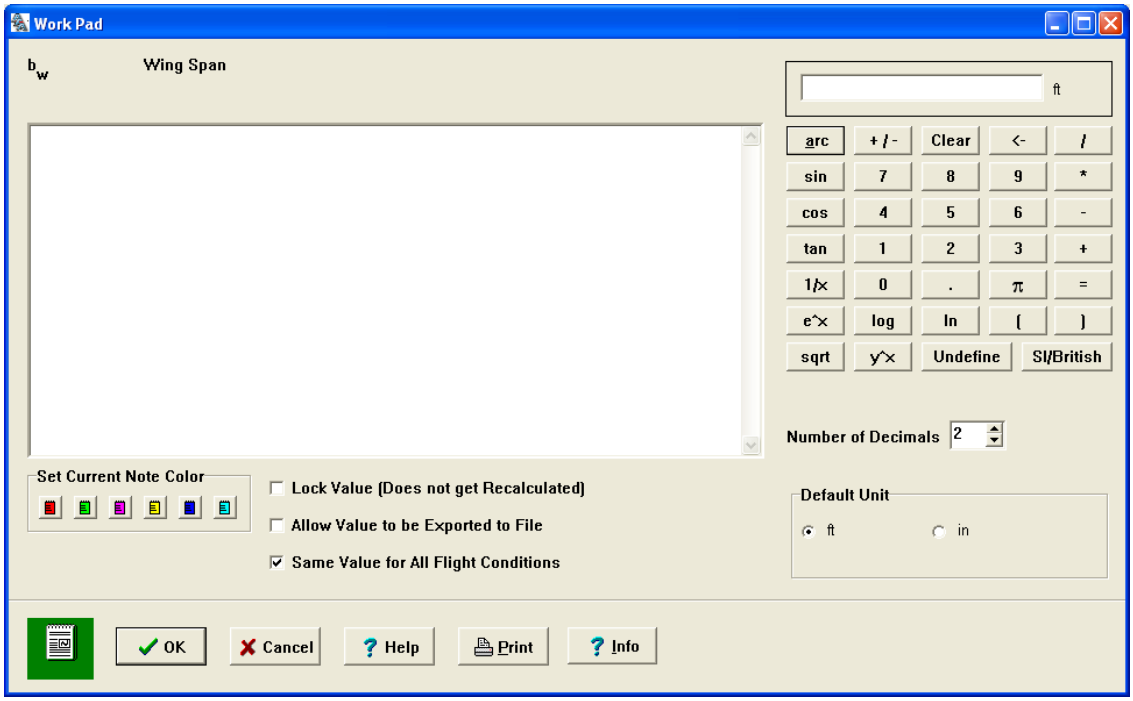


Figure 2.4 Work Pad Window

An input/output window can also contain a table for numeric input and output data (see Figure 2.2). Rows can be added to or subtracted from certain tables to account for multiple inputs of the same form. For example, the fuselage can be divided into two or more sections for moment calculations. Figure 2.2 shows an input/output window with a table for fuselage section input. The table can be resized (rows added or subtracted) using the spin edit element, which appears as the last element in the input menu (see Figure 2.2). The spin edit element is similar in appearance to an input/output element. The number of rows of a table can be changed by clicking on the arrows in the spin edit element.

The work pad window can be used to maintain notes of a particular project. This window can also be used to change the units of a specific parameter and maintain notes about the parameter (see Figure 2.4). The input menu of the input/output window may also contain a combo box element (see Figure 2.5). The combo box element is similar in appearance to an input/output element, but does not contain an edit box. The combo box element contains a list of choices that affect the calculation results. The list of choices is displayed by clicking on the arrow at the right side of the element and holding down the left mouse button. A choice can then be made by moving the cursor to the appropriate choice and releasing the mouse button.

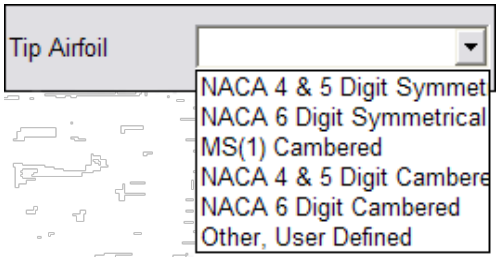


Figure 2.5 Combo Box Element

Most input/output windows contain an output group of elements showing the results of the calculation performed in the window. The output group can contain output elements or a table of values. The output results of some input/output windows can be displayed as a graph or plot. The plot of the output is presented in a plot window when the Plot button on the input/output window command bar is selected. The plot window is described in the Subsection 2.1.4.

2.1.3 Input/Output Window Command Bar

The input/output window command bar is displayed at the top of the input/output window. The input/output window command bar is shown in Figure 2.6. Each button in the command bar represents an action that can be performed in the input/output window. A command bar button is not displayed if its action is not available for the particular input/output window. The Close button in the command bar closes the input/output window and is always displayed. The remaining buttons that can be displayed in the input/output command bar are shown and described in Table 2.2.

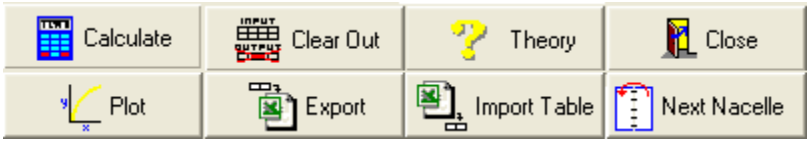


Figure 2.6 Input/Output Window Command Bar Buttons

Table 2.2 Input/Output Window Command Bar Functions

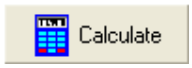
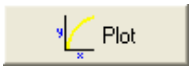
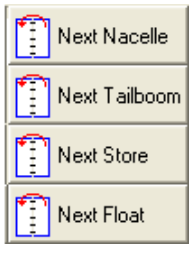
	**Calculate:** Using the specified input, the calculations for the input/output window are performed. The results of the calculations are displayed in the output parameters.
	**Plot:** Opens the corresponding Plot window when applicable.
	**Next Item:** If there are multiple tables of input (for example, tables for different nacelles, tailbooms and stores) needed for the calculation, the next table of parameters will be displayed. If the last table is currently displayed, the first table will be displayed after selecting this button.
	Clear Out: Allows the user to erase all output parameters in the output section of the calculation window.
	Import: Imports an Excel file in the same format as the table in the active window

Table 2.2 (Contd.) Input/Output Window Command Bar Functions

Export	**Export:** Export input and output data to a text file (ASCII), or to an Excel Spreadsheet.
Theory	**Theory:** Opens a Help window containing the calculation methods corresponding to the input/output window (see Section 6.3).
Close	**Close Window:** Closes the input/output window. The window minimize button can be used to iconize the window if desired.

2.1.4 Plot Windows

The plot window contains a graphical representation of a calculation in an input/output window. Figure 2.7 shows a plot window of a Class I drag polar of a jet-powered airplane. The plot window contains a command bar at the top. The functionality of the plot window command bar is described in Subsection 2.1.5.

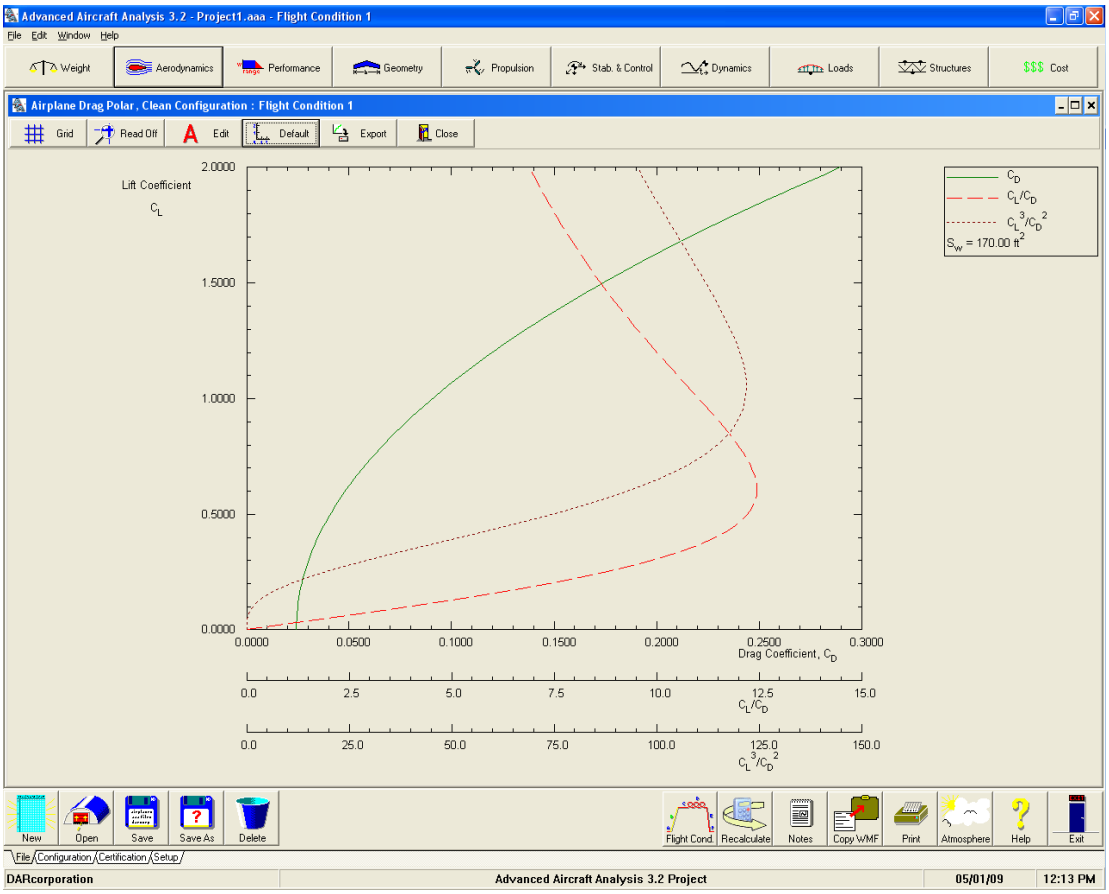


Figure 2.7 Plot Window

Most plot windows contain a legend at the top right corner of the window. Plot windows also contain one or more vertical and one or more horizontal axes. When the cursor is moved over an axis, it appears as horizontal and vertical axes. When the cursor changes, the left mouse button can be double clicked, and a dialog will be displayed allowing the user to change the axes (see Figure 2.8). The minimum and maximum values, the major and minor divisions and the number of displayed decimal places can be changed. If the axes are expanded beyond the original range of the calculation, the plotted parameters will not be recalculated for the expanded range. To recalculate the parameters, the user should close the plot window and increase the range of calculation in the input/output window. The first time the program creates a specific plot, the software calculates the plot area to encompass the entire graph. The values defining the first plot area will be saved and used the next time the plot is generated. If the axes are changed to redefine the plot area, those parameters will be saved and used the next time the graph is generated. The parameters are saved for every plot that can be generated in the software. The parameters are saved in the user database. The user can always have the program recalculate the plot area to show the entire graph by selecting the **Default** button in the plot window command bar.

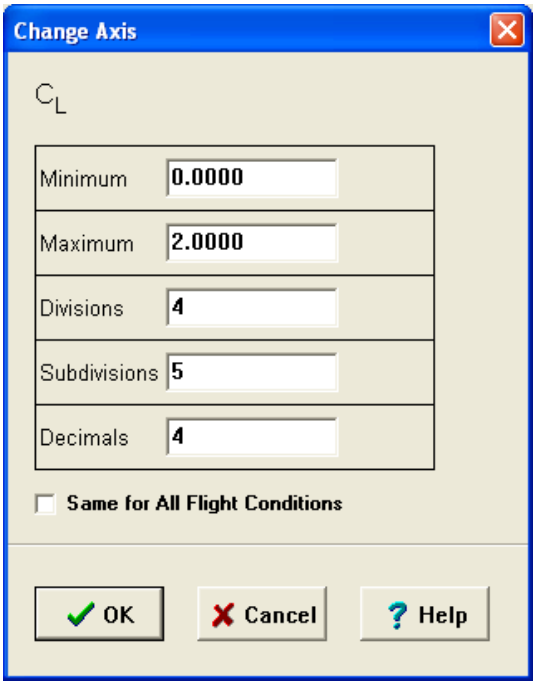


Figure 2.8 Change Axis Dialog

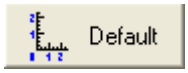
The functionality of the plot window command bar buttons is described in the next subsection.

2.1.5 Plot Window Command Bar

The plot window command bar is displayed at the top of the plot window. The plot window command bar is shown in Figure 2.9. Each button in the command bar represents an action that can be performed in the plot window. A command bar button is not displayed if its action is not available for the particular plot window. The Close button in the command bar closes the plot window and is always displayed. The remaining buttons that can be displayed in the plot command bar are shown and described in Table 2.3.

Figure 2.9 Plot Window Command Bar Buttons

Table 2.3 Plot Window Command Bar Buttons

	Grid: Allows the user to turn the axis grid on or off on the plot.
	Read Off Graph: Allows the user to read a value from the plot. When selected, the corresponding X and Y coordinates are displayed when the user positions the cross hairs on the plot by holding down the left mouse button. The cross hairs will be set at the instant that the mouse button is released.
	Edit: Allows the user to modify the font of all text displayed on the plot window.
	**Default:** Recalculates the axes so that the whole graph will show up on the plot window.
	Export: Export input and output data to a text file (ASCII), or to an Excel Spreadsheet.
	Close: Closes the plot window. The window minimize button can be used to iconize the window if desired.

2.2 Toolbars

The program main window contains five toolbars located above the status bar (Figure 2.1). The main toolbar is located on the right and is always visible. The four remaining toolbars can be displayed by clicking on the corresponding tab underneath the currently displayed toolbar on the left side of the main window. The five toolbars are described in the following subsections:

2.2.1 The Main toolbar (see Figure 2.1)

2.2.2 The File toolbar, displayed by clicking on the File tab (see Figure 2.1)

2.2.3 The Configuration toolbar, displayed by clicking on the Configuration tab

2.2.4 The Certification toolbar, displayed by clicking on the Certification tab

2.2.5 The Setup toolbar, displayed by clicking on the Setup tab

2.2.1 Main Toolbar

The main toolbar (Figure 2.10) consists of seven fixed bitmap buttons at the bottom right of the main window. The main toolbar supplies general functions needed throughout the program. The functionality of the buttons in the main toolbar is described in Table 2.4.

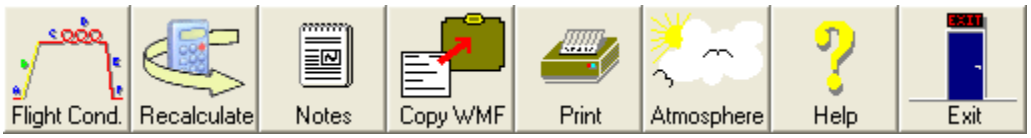


Figure 2.10 Main Toolbar

Table 2.4 Toolbar Buttons

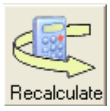
	Flight Condition: Set and define each flight condition to be included in the analysis. An airplane project can have up to 95 flight conditions defined.
	**Recalculate:** Calculates the output parameters of different modules for selected flight conditions.

Table 2.4 (Contd.) Toolbar Buttons

	Notes: Record general notes about the current project. Notes are saved with the project.
	Copy WMF: Copy a representation of the active window into the clipboard in Windows Metafile Format. The contents of the clipboard can then be pasted into a word processing or drawing program that supports Windows Metafiles. The contents can also be saved to files if the *Copy WMF to File* option in the Program Options dialog box (Figure 2.31) in the Setup toolbar is checked.
	Print: Make a hard copy of the data currently displayed on the screen on the selected printer. Printing options are described in Chapter 4.
	Atmosphere: Display an input/output window for calculation of properties of the standard atmosphere at a given altitude and temperature offset. The module also calculates Mach number and Reynolds number per unit length.
	Help: Display the help system associated with the software. Chapter 6 describes the help system.
	Exit: Exit the program.

The **Flight Condition** button displays the Flight Condition Definition dialog box, which is shown in Figure 2.11.

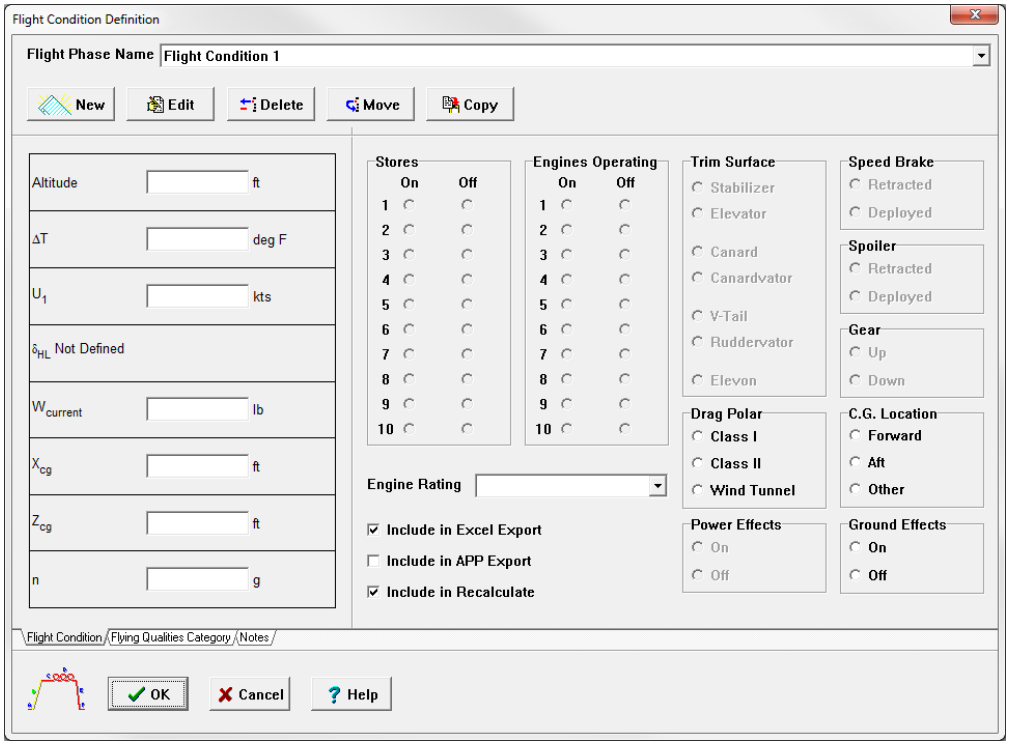


Figure 2.11a Flight Condition Dialog Box

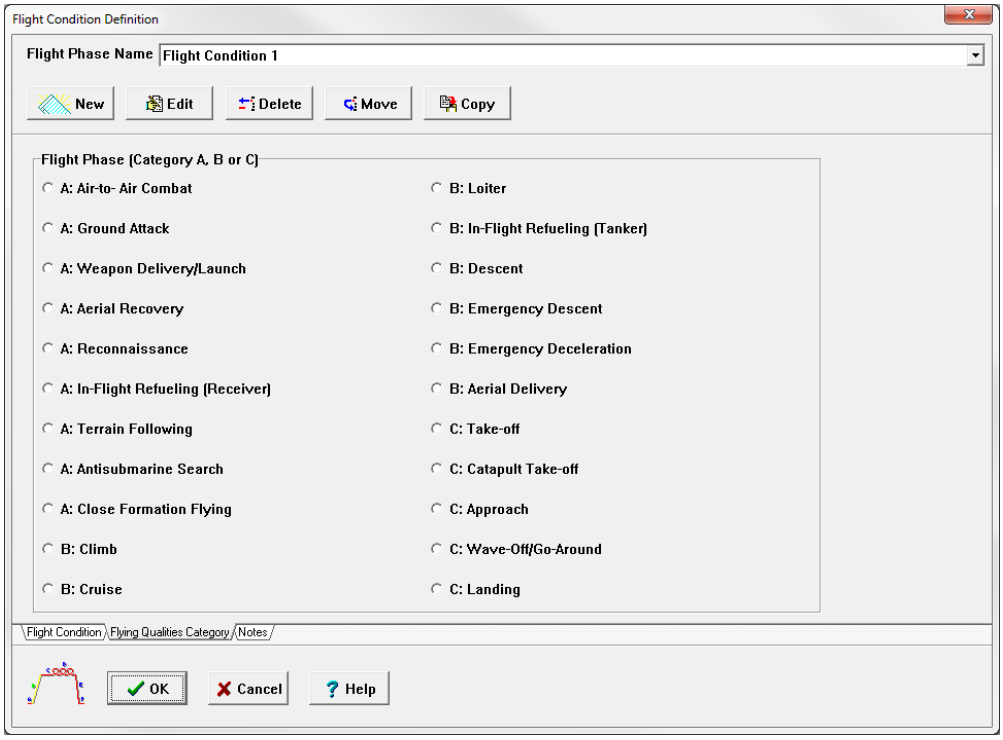


Figure 2.11b Flight Condition Dialog Box (Contd.)

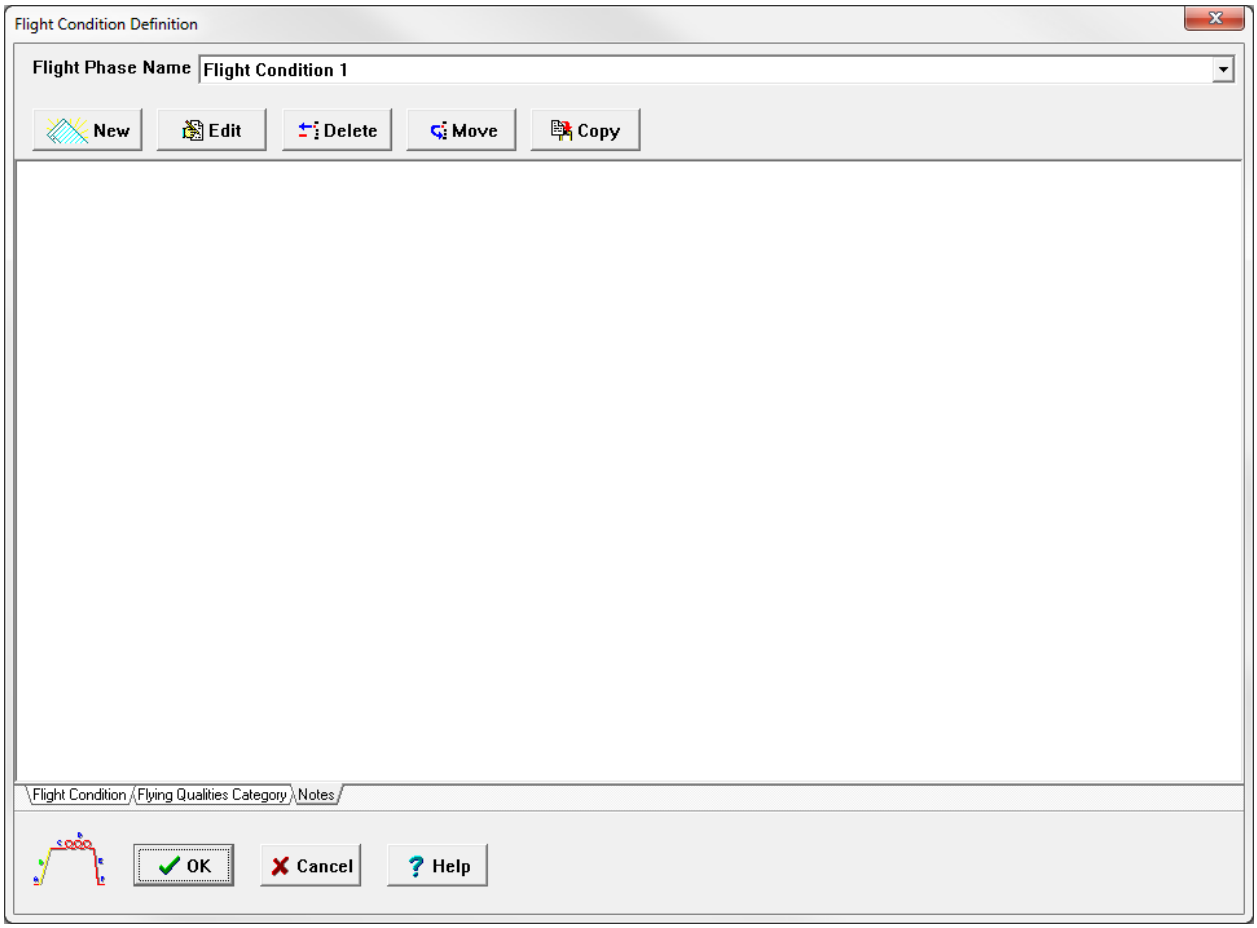


Figure 2.11c Flight Condition Dialog Box (Contd.)

The options available to the user in the Flight Condition Definition dialog box are described as follows:

- Flight Phase Name: The user can select the name of the flight phase for which the present analysis is to be performed (i.e. take-off, climb, cruise, etc.). The defined phases appear in the drop-down list to be selected by the user. Only one flight phase can be analyzed at one time. The program can handle up to 95 different flight conditions.
- New: The user can define a new flight phase.
- Edit: The user can change the name of the current flight phase.
- Delete: The user can delete a flight phase from the current project. All information associated with the selected flight phase will be deleted.
- Move: The user can move a flight phase within the current project.
- Copy: The user can copy a flight phase within the current project.

- Altitude: The user enters the altitude corresponding to the defined flight phase.
- Temperature Increment: The user can enter a temperature offset from standard atmosphere.
- Velocity: The user enters the velocity for the defined flight condition. British or S.I. units are automatically supplied depending on the setting in the Units dialog box (see Figure 2.25).
- Flap Deflection: After defining trailing edge flap in the configuration dialog box, the user enters the flap deflection angle corresponding to the flight condition.
- Current Weight: The user enters the current weight of the aircraft corresponding to the defined flight phase.
- C.G. X-Location: The user enters the current Center of Gravity location along the X-axis for the defined flight condition.
- C.G. Z-Location: The user enters the current Center of Gravity location along the Z-axis for the defined flight condition.
- Load Factor: The user enters the load factor corresponding to the defined flight phase.
- Stores: After defining stores in the Configuration dialog box, the user can specify which stores are on the airplane in the specified flight condition.
- Engines Operating: The user can indicate which engines are operating in that flight condition.
- Engine Rating: The user may select the following options using this drop down list
    1. Take-off
    2. Max Continuous
    3. Max Cruise
- The user may select any of the given options “Include in Recalculate”, “Include in Export” to include the flight condition to the “Recalculate” Dialog window and to include the flight condition to “Export to Excel” option in the “Recalculate” Dialog window.
- Trim Surface: The user can indicate which control surface is used for trim in the current flight condition.
- Canard Trim: For Canard configurations, the user might select a variable incidence canard or a canardvator for trim. This selection can be done simultaneously with any

tail-aft control surface.

- Drag Polar: The user can indicate which drag polar is to be used for Trimmed Lift (T from D), Longitudinal Trim, Trim Diagram and Performance > Analysis > Maximum Cruise Speed modules.
- Power Effects: For propeller driven airplanes, the user can indicate if power effects are ON or OFF for the flight condition.
- Speed Brake: After selecting speed brake in the Configuration dialog box, the user can specify if the speed brake is retracted or deployed for the corresponding flight phase.
- Spoilers: After selecting spoiler in the Configuration dialog box, the user can specify if the spoiler is retracted or deployed for the corresponding flight phase.
- Gear: After defining the number and location of the gear in the Gear dialog box, the user can select landing gear position, retracted (up) or extended (down) for the corresponding flight phase.
- C.G. Location: The user can specify whether the flight condition corresponds to forward or aft C.G. or any other C.G. location.
- Ground Effects: The user can indicate whether the ground effects are ON or OFF for the flight condition.
- Flight Qualities Category: The flight phase and category (used in flying quality evaluation) can be specified for the flight condition.
- Notes: The user may enter notes that will be saved with the flight condition.

The **Recalculate** button (see Figure 2.12) on the main toolbar allows the user to recalculate:

a. Class II Weight
b. Component C.G.
c. Empty Weight C.G.
d. Fuel Weight C.G.
e. C.G.
f. Forward/Aft C.G.
g. Landing Gear Geometry
h. Lift

i. Maximum Lift
j. Pitching Moment
k. Stability and Control Derivatives
l. Class II Drag
m. Trimmed Drag Trend Line
n. Untrimmed Drag Trend Line
o. Drag from Trend Line
p. Critical Mach Number
q. Steady State Coefficients
r. Hinge Moment Derivatives
s. Trimmed Lift (T = Const)
t. Trimmed Lift (T from D)
u. Transfer Functions
v. Flying Qualities
w. Static Margin
x. V-n Diagram
y. Plot V-n Diagram
z. Plot Trim Diagram

This can be done for each flight condition separately where the user can select which features need to be recalculated, or the user can choose to automatically run through a series of flight conditions marked in the Flight Condition window. Trim diagrams can automatically be exported to WMF files and saved to the harddisk for each flight condition. Marked variables can also be exported automatically to Excel spreadsheets. This powerful tool allows the user to quickly and accurately create a picture of the aircraft aerodynamics and stability and control issues through a wide range of flight conditions at the click of a button.

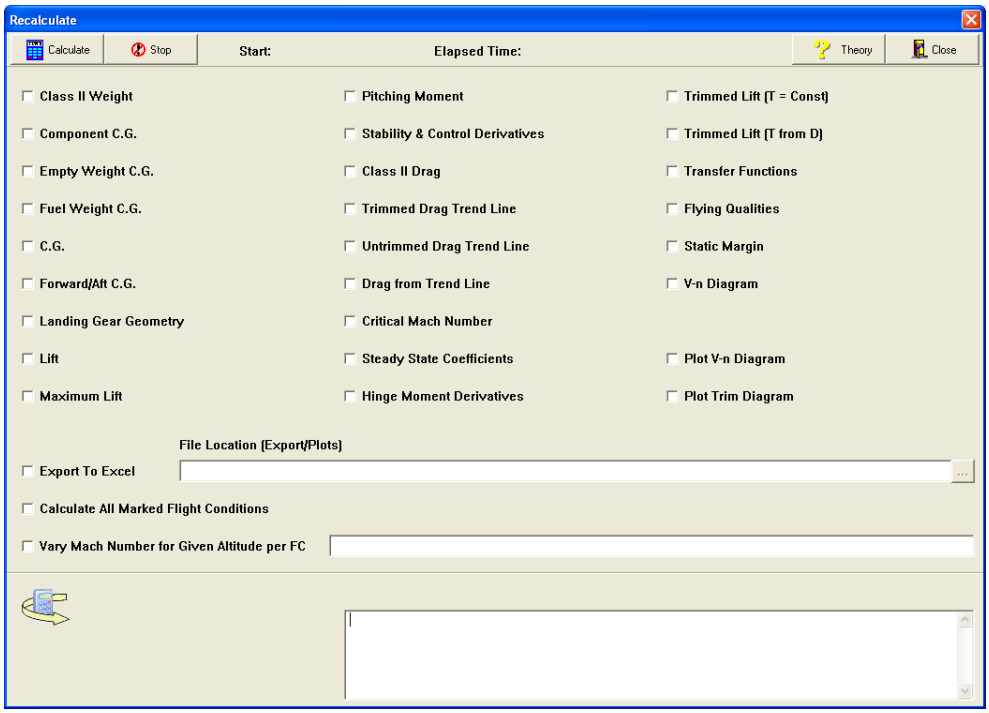


Figure 2.12 Recalculate Dialog

When the **Print** button on the main toolbar is selected, the current print settings defined in Print and Print Setup under the File menu are used to print the output directly with no user interaction. Using Print and Print Setup under the File menu, the user can manipulate the print style, (see Figure 2.13) before the print command is sent to the printer.

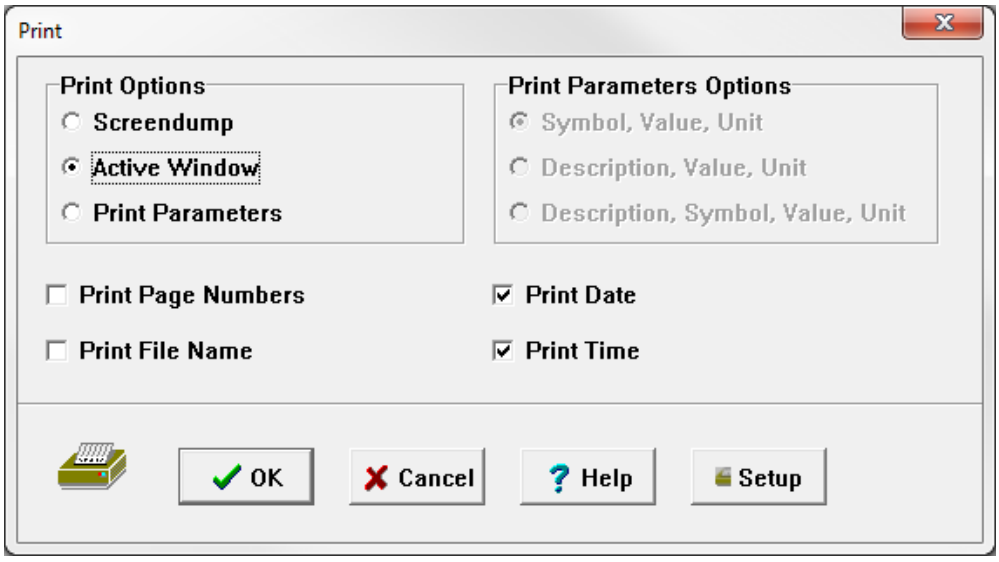


Figure 2.13 The Print Dialog

The Print dialog box options are described in Chapter 4. In brief, the Print dialog box options are:

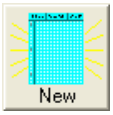
- Screendump: Prints a bitmap representation of the main window and any other open and visible windows.
- Active Window: Prints a graphic representation of the active application, input/output, or plot window.
- Print Parameters: Prints a list of the input and output parameters in an input/output window. The Print Parameters option has three options:
  - Symbol, Value, Unit: Prints the parameter symbol, the value, and the unit.
  - Description, Value, Unit: Prints the description of the parameter, the value, and the unit.
  - Description, Symbol, Value, Unit: Prints the parameter description, symbol, value, and unit
- The user can also choose whether to show the date, time, page number and file name on the print out.

2.2.2 The File Toolbar

The File toolbar (Figure 2.14) consists of five bitmap buttons at the bottom of the main window. The File toolbar buttons can be used to manage projects and files of the software. The functionality of the buttons in the File toolbar is described in Table 2.5.

Figure 2.14 File Toolbar

Table 2.5 File Management Toolbar Buttons

	**New:** Create a new project.
	Open: Open an existing project (*.analys files from AAA Versions 1.0 through 1.7 and *.gpr files from AAA 2.0 through AAA 2.2 can also be opened).
	Save: Quickly save the current project under its current name and directory. Files have an *.aaa extension.
	Save As: Save the current project under a different name and/or folder. The project is saved in a directory (folder) with the same name as the project.
	Delete: Remove any Project.

Each of the buttons in the File Management toolbar opens the Windows dialog box corresponding to that function. Descriptions of the dialog boxes can be found in the documentation for your version of Windows.

2.2.3 Configuration Setup Toolbar

The Configuration Setup toolbar (Figure 2.15) consists of six bitmap buttons at the bottom of the main window. The Configuration Setup toolbar buttons can be used to define the airplane configuration for the current project. The functionality of the buttons on the Configuration Setup toolbar is described in Table 2.6.

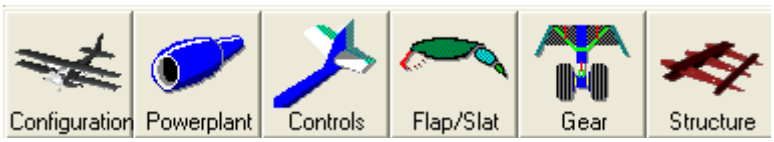


Figure 2.15 Configuration Setup Toolbar

Table 2.6 Configuration Setup Toolbar Buttons

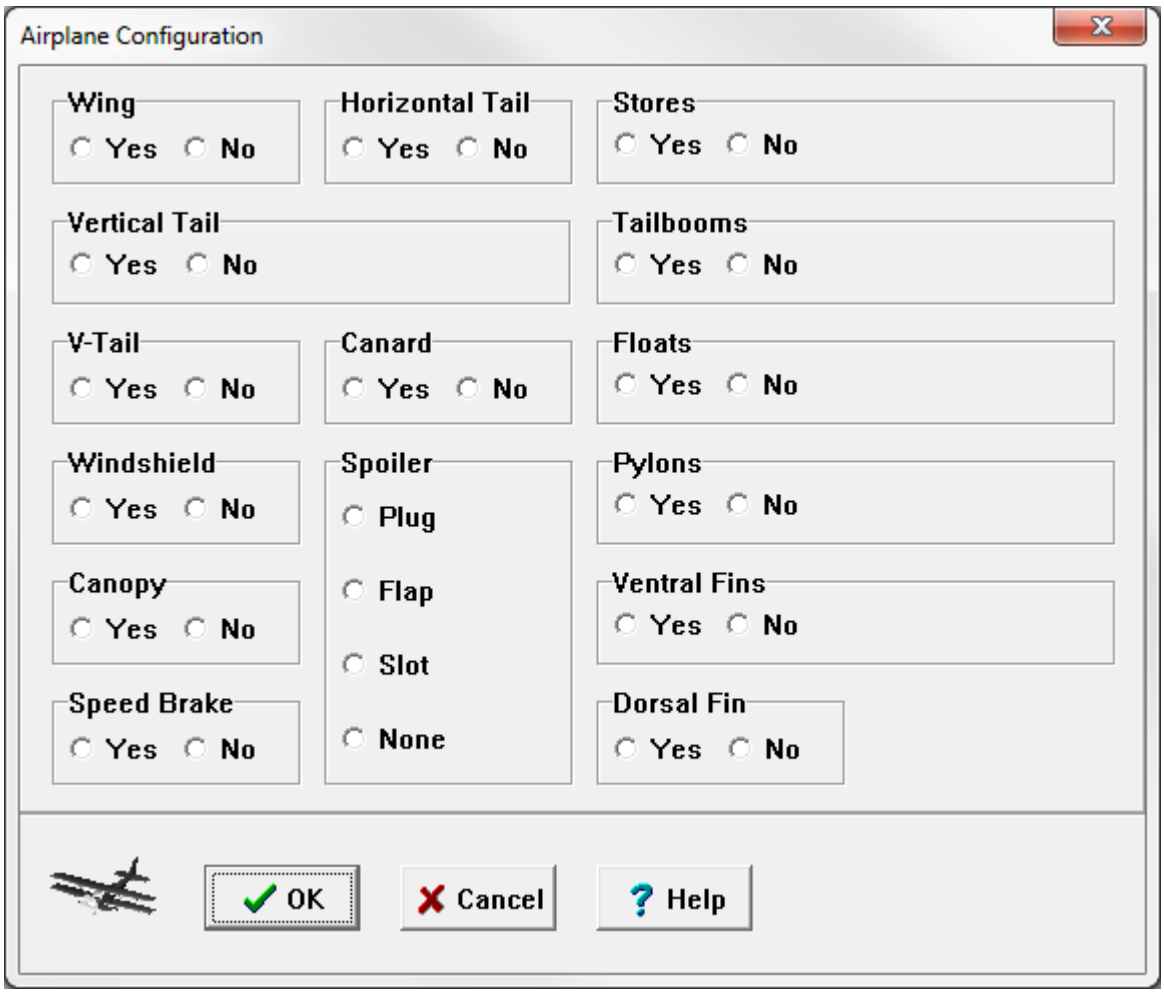
	Configuration: Define the basic configuration of the airplane, which includes empennage, nacelle(s), store(s), pylon(s), tailboom(s), speed brake and spoiler. In the case of stores, speed brake and spoiler, the flight condition dialog box is used to define whether the devices are deployed in the current flight phase.
	Engine: Define various aspects of the propulsion system of the airplane.
	Controls: Define longitudinal and directional control surfaces for the airplane.
	Flap/Slat: Define the number and type of high lift devices per wing.
	Gear: Define the type of landing gear position, retraction and attachment point. In the case of retractable gears, the Flight Condition dialog is used to define whether the gear is extended or retracted in the flight phase.
	Structure: Define the cross-section structure type of wing and empennage, amphibious hull, pressurization and attachment types for the wing and the empennage.

Each of the buttons in the Configuration Setup toolbar opens a dialog box when selected. The remainder of this subsection will present the dialog boxes opened by the Configuration Setup toolbar buttons.

Airplane Configuration Dialog Box

When the **Configuration** button is selected, the Airplane Configuration dialog box is displayed. Figure 2.16 shows the Airplane Configuration dialog box. The user can define the basic configuration of the airplane using this dialog box. For vertical tail, nacelles, stores, tailbooms, floats, pylons and ventral fins the number of each device can also be defined using this dialog

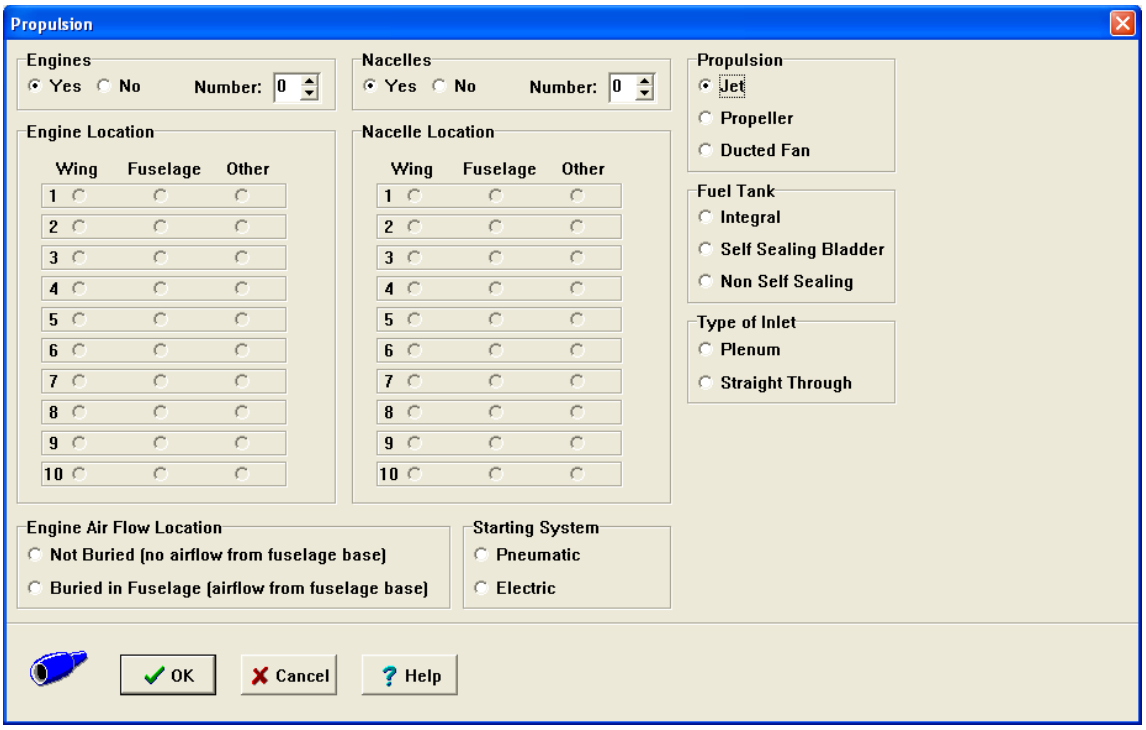
box.



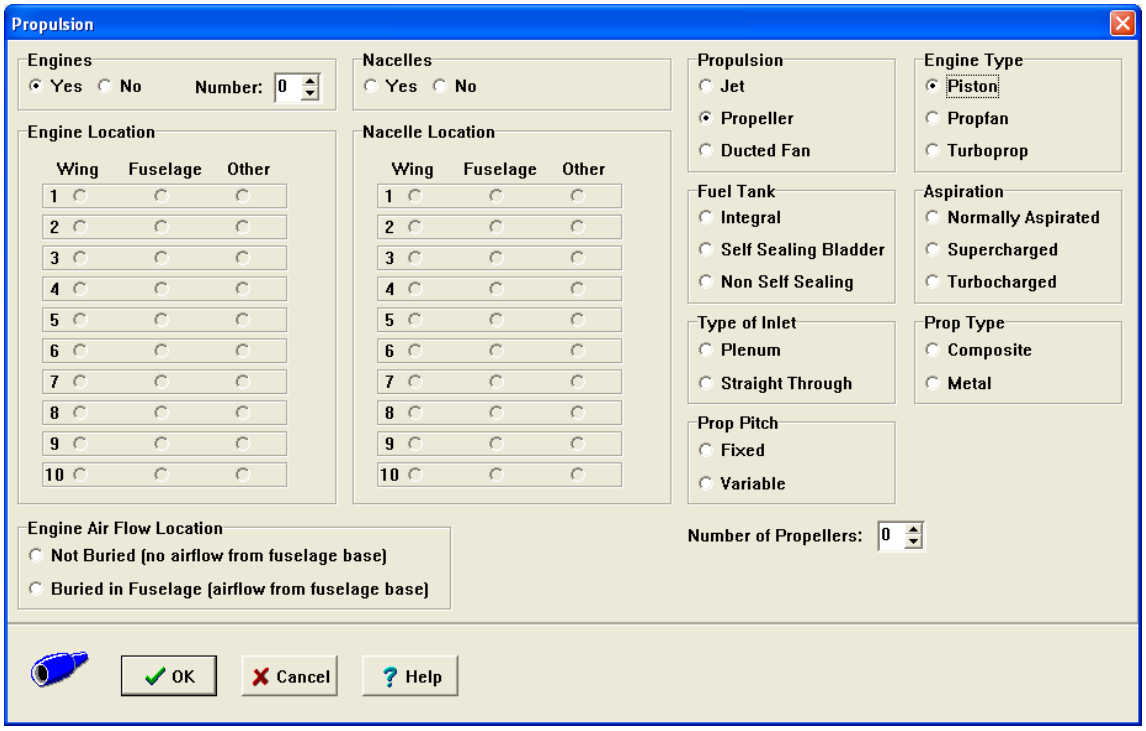
Figures 2.16 Airplane Configuration Dialog Box

Propulsion Selection Dialog Box

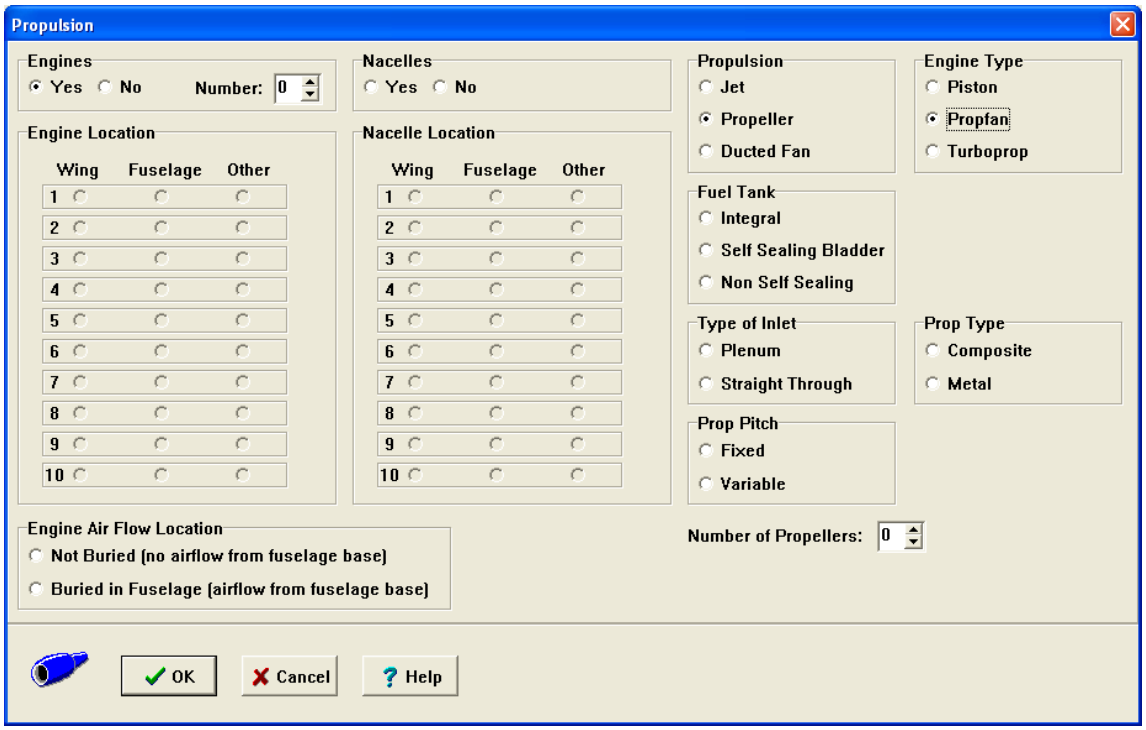
When the **Engine** button is selected, the Powerplant Selection dialog box is displayed. Figure 2.17 shows the Powerplant Selection dialog box. Different options will show up on the dialog box depending on the engine selected. Descriptions of the dialog box functions follow.



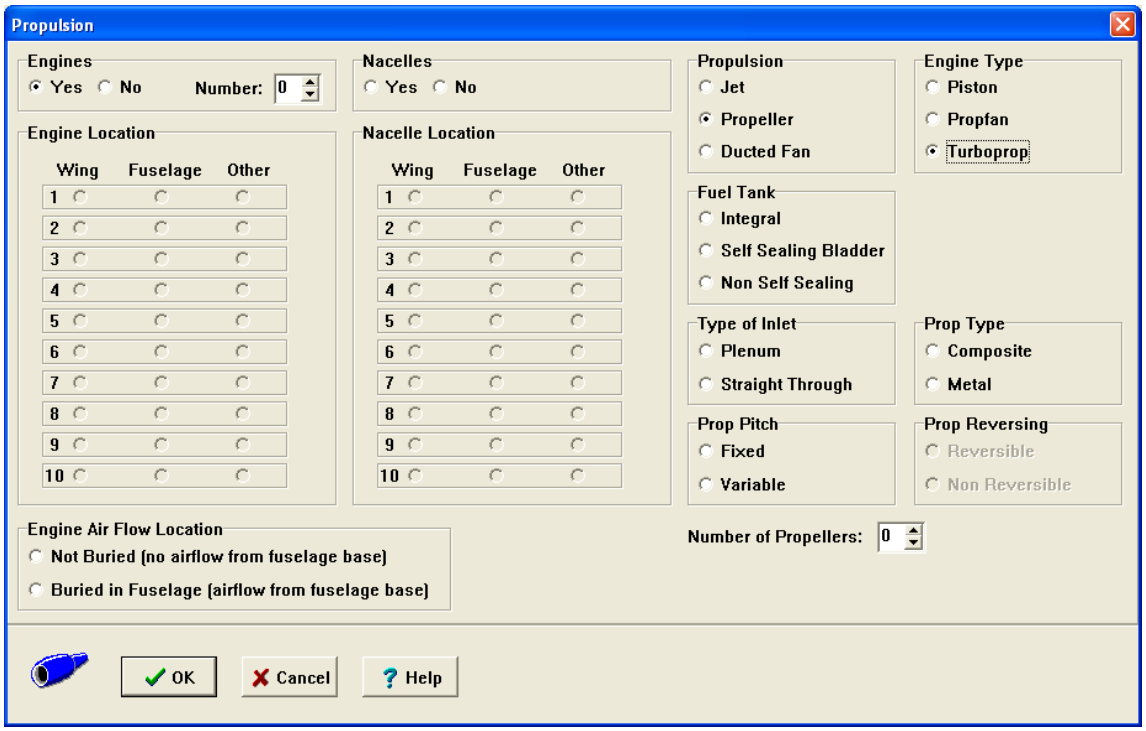
Figures 2.17a Powerplant Selection Dialog Box for a Jet



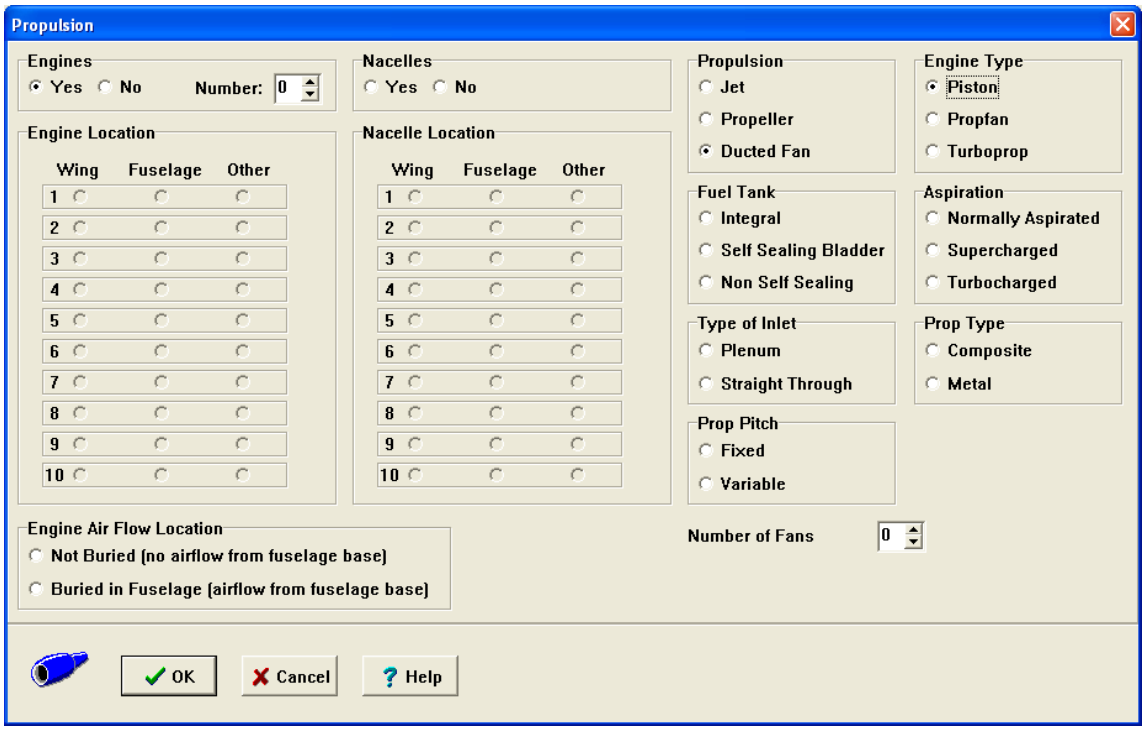
Figures 2.17b Powerplant Selection Dialog Box for a Propeller-Piston



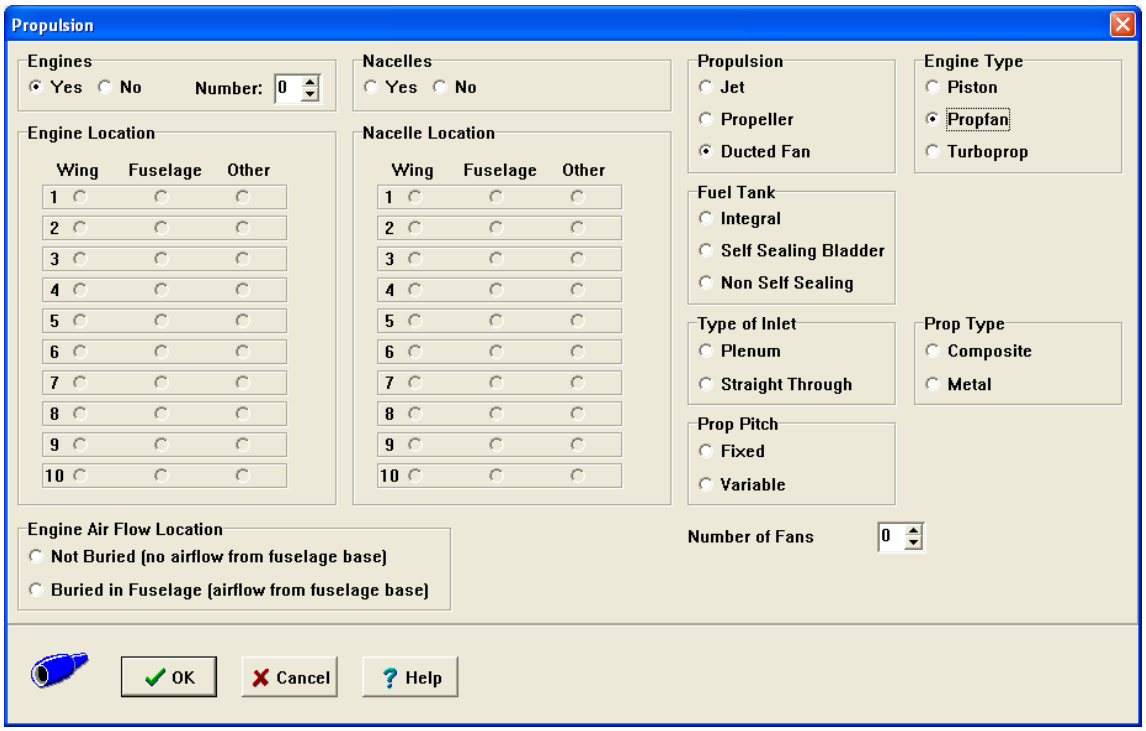
Figures 2.17c Powerplant Selection Dialog Box for a Propeller-Propfan



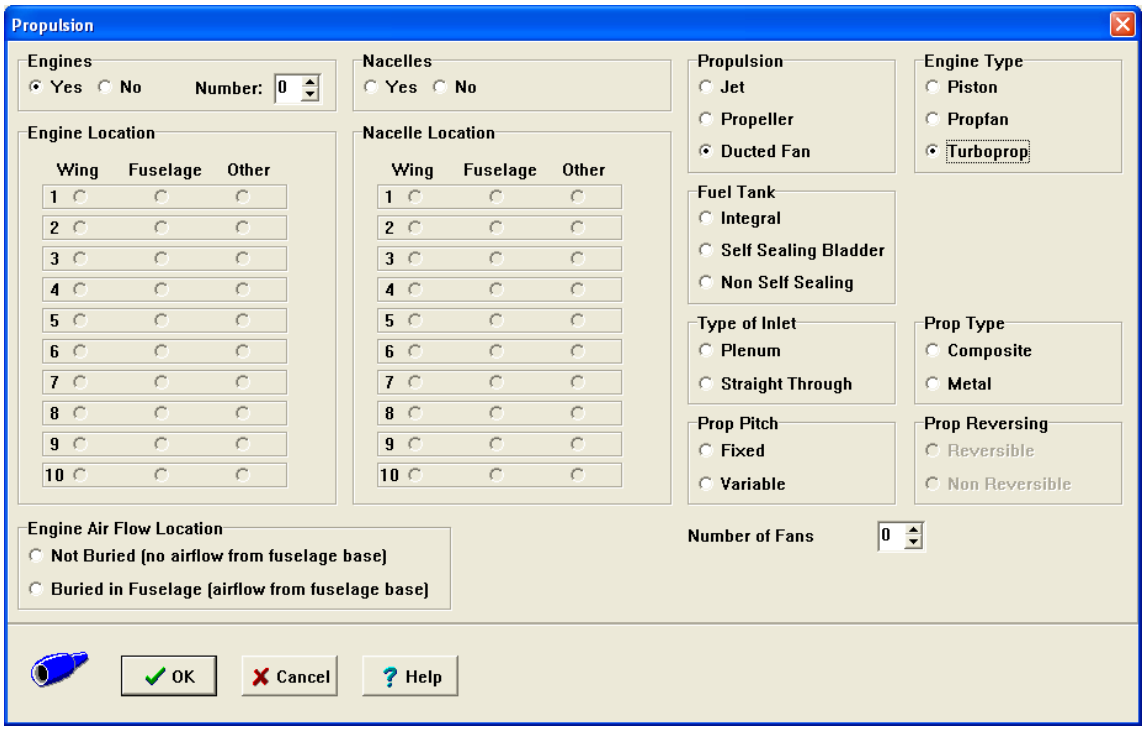
Figures 2.17d Powerplant Selection Dialog Box for a Propeller-Turboprop



Figures 2.17e Powerplant Selection Dialog Box for a Ducted Fan-Piston



Figures 2.17f Powerplant Selection Dialog Box for a Ducted Fan-Propfan



Figures 2.17g Powerplant Selection Dialog Box for a Ducted Fan-Turboprop

- Engines: The user can specify if there are engines.
- Number of Engines: For all engine types, the user can define the number of engines.
- Engine Location: The user can specify where the engines are located.
- Nacelles: The user can specify if there are nacelles.
- Number of Nacelles: The user can define the number of nacelles.
- Nacelle Location: The user can specify where the nacelles are located.
- Propulsion: The user can define a jet, propeller, or a ducted fan.
- Engine Type: The user can specify the engine to be a piston, propfan or a turboprop for a propeller or a ducted fan.
- Aspiration: For a piston driven propeller or ducted fan, the user can specify whether the engine is normally aspirated or supercharged or turbocharged.
- Fuel Tank: For all engine types, the type of fuel tank can be specified.
- Type of Inlet: For all engine types, the type of engine inlet can be specified.
- Number of Propellers: For all engine types except jet, the user can define the number of propellers. The number of propellers can be different from the number of engines.

- If Jet is selected for the powerplant type (Figure 2.17a), the type of starting system can be specified.
- If Propeller or Ducted Fan is selected for the Propulsion type and Piston is selected Engine Type, the following options are available:
  - Propeller Pitch: The user can choose a variable or fixed pitch propeller.
  - Propeller Type: The user can choose a metal or composite propeller.
  - Aspiration: The user can define aspiration.
- If Propeller or Ducted Fan is selected for the Propulsion type and Propfan or Turboprop is selected as the Engine Type, the following options are available:
  - Propeller Pitch: The user can choose a variable or fixed pitch propeller.
  - Propeller Type: The user can choose a metal or composite propeller.
  - Propeller Reversing (For Ducted Fan and Turboprop only): The user can choose a reversible or non-reversing propeller.

Controls Configuration Dialog Box

When the **Controls** button is selected, the Control Surface Configuration dialog box is displayed. The dialog box contains different pages for wing, horizontal tail, vertical tail, v-tail and canard. The user can display different pages by clicking on the corresponding tab on the lower left corner of the dialog box. Figure 2.18 shows the Control Surface Configuration dialog box with the wing and horizontal tail page displayed, respectively. The canard, vertical tail and v-tail pages are similar to that of the horizontal tail.

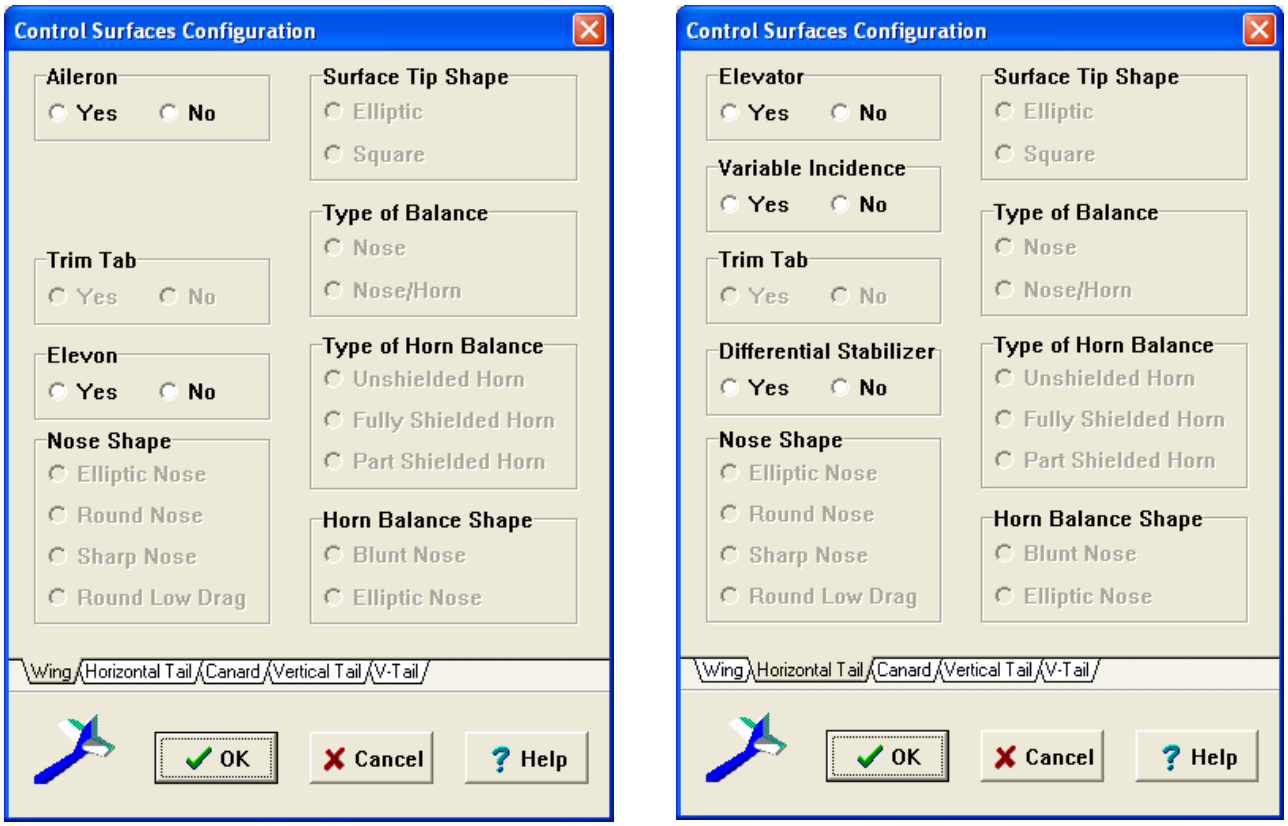


Figure 2.18 Control Surface Configuration Dialog Box

The dialog box displayed in Figure 2.18 allows the user to define the appropriate control surfaces for the airplane, i.e. aileron, elevator, canardvator, ruddervator and rudder. Respective control surfaces are disabled when an empennage surface is not selected. Descriptions of the dialog box functions follow.

- Control Surface: On the Wing page, the user can select aileron, drooped aileron, aileron trim tab and elevon. On other pages, a flap-type control (elevator, canardvator, ruddervator and rudder), variable incidence, and trim tab can be chosen. The horizontal tail can include a differential stabilizer for roll control.
- Surface Tip Shape: The stability surface tip shape can be chosen for hinge moment estimations.
- Nose Shape: The aileron, elevator, canardvator and rudder nose shapes can be chosen for hinge moment estimations
- Type of Balance: The type of balance of the aileron, elevator, canardvator and rudder can

be chosen.

- Type of Horn Balance: If the aileron, elevator, canardvator or rudder includes a horn balance, the type of horn balance can be chosen.
- Horn Balance Shape: For fully or partially shielded aileron, elevator, canardvator and rudder horns, the horn nose shape can be chosen.

Flap/Slat Dialog Box

When the Flap/Slat button is selected, the Flap/Slat dialog box is displayed. The dialog box displayed in Figure 2.19 allows the user to select the number and type of high lift devices per wing. Descriptions of the dialog box follow.

- Number of High Lift Devices per Wing: The user may specify the number of high lift devices per wing
- Trailing Edge Device: The user may specify the type of trailing edge device from the list given in Figure 2.19
- Leading Edge Device: The user may specify the type of leading edge device from the list given in Figure 2.19

Figure 2.19 High Lift Devices Dialog Box

Landing Gear Dialog Box

When the **Gear** button is selected, the Landing Gear dialog box is displayed. Figure 2.20 shows the Landing Gear dialog box. Descriptions of the dialog box functions follow.

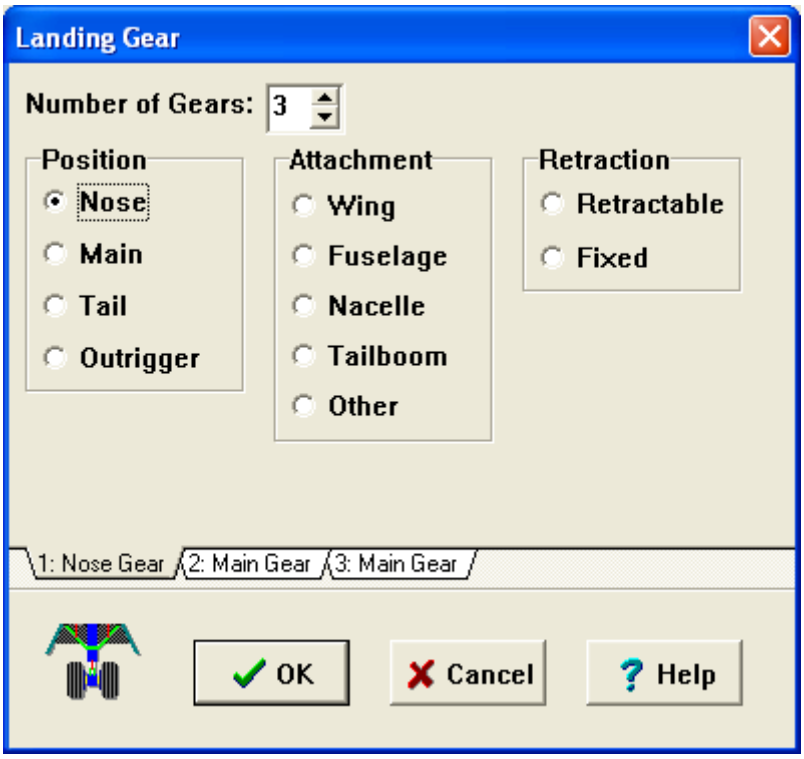


Figure 2.20 Landing Gear Configuration Dialog Box

- Number of Gears: The user may specify the number of gears. Each strut should be considered as one landing gear.
- Position: The relative position (nose, main or tail) of each gear can be specified.
- Retraction: The retraction capability (retractable or fixed) of each gear can be specified.
- Attachment: The location (wing, fuselage, nacelle, tailboom or other) of where the gear is attached can be specified.

Structure Dialog Box

When the **Structure** button is selected, the Structure dialog box is displayed. The user can choose from the five different structure types, as shown in the pull-down list in Figure 2.21, for each surface. The user can also specify if the surface is attached to the fuselage.

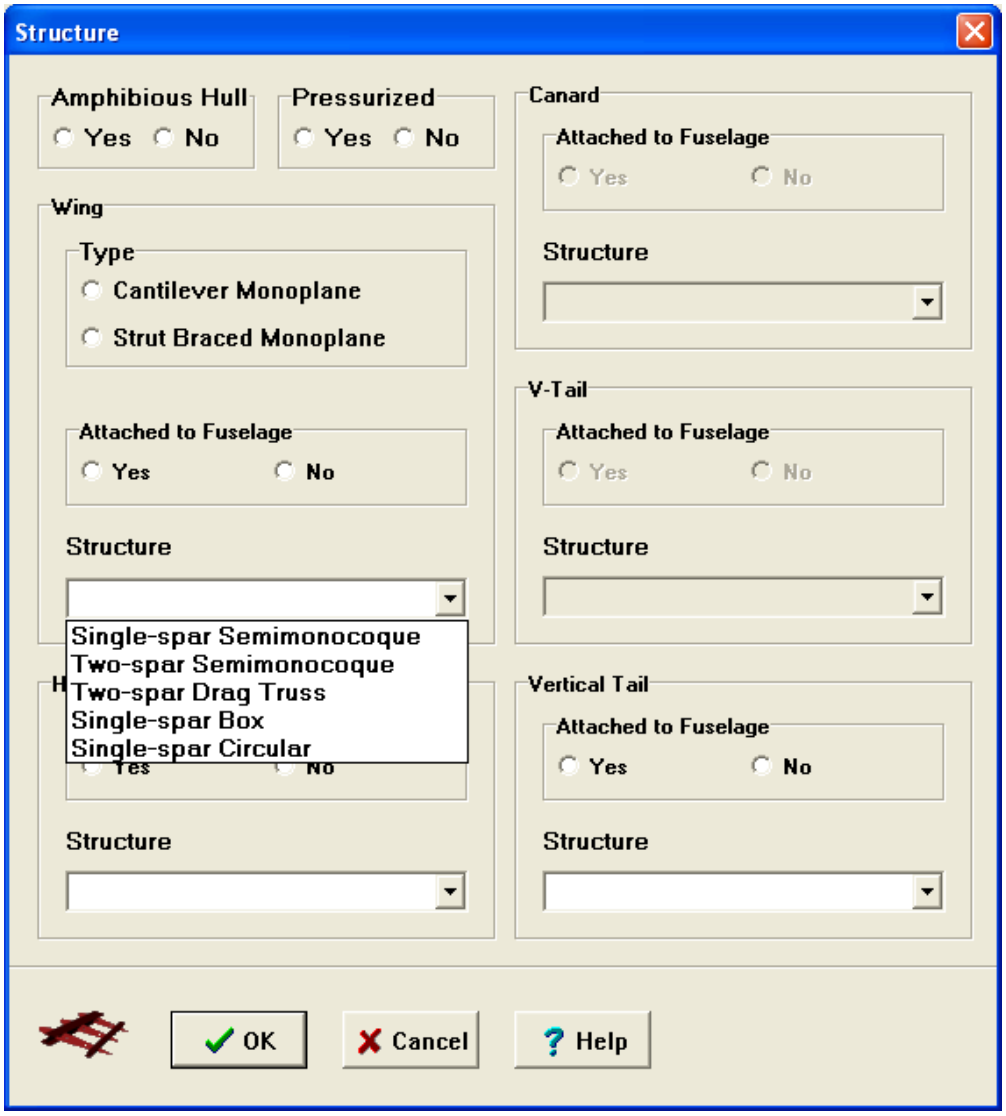


Figure 2.21 Lifting Surface Cross-Section Structure Dialog Box

2.2.4 Certification Toolbar

The Certification toolbar (Figure 2.22) consists of two bitmap buttons at the bottom of the main window. The Certification toolbar buttons can be used to specify airplane certification type and class. The functionality of the buttons on the Certification toolbar is described in Table 2.7.

Figure 2.22 Certification Toolbar

The functions of the buttons shown in Figure 2.22 are described in Table 2.7.

Table 2.7 Certification Toolbar Buttons

	Certification: Define the airplane type, category and certification under civil and military regulations.
	Classification: Define the class of the airplane for US military flying qualities regulations to evaluate flying qualities for both civilian and military airplanes.

Certification and Type Dialog Box

When the **Certification** button is selected, the Certification and Type dialog box is displayed. Figure 2.23 shows the Certification and Type dialog box for civil airplanes and military airplanes. Descriptions of the dialog box functions follow.

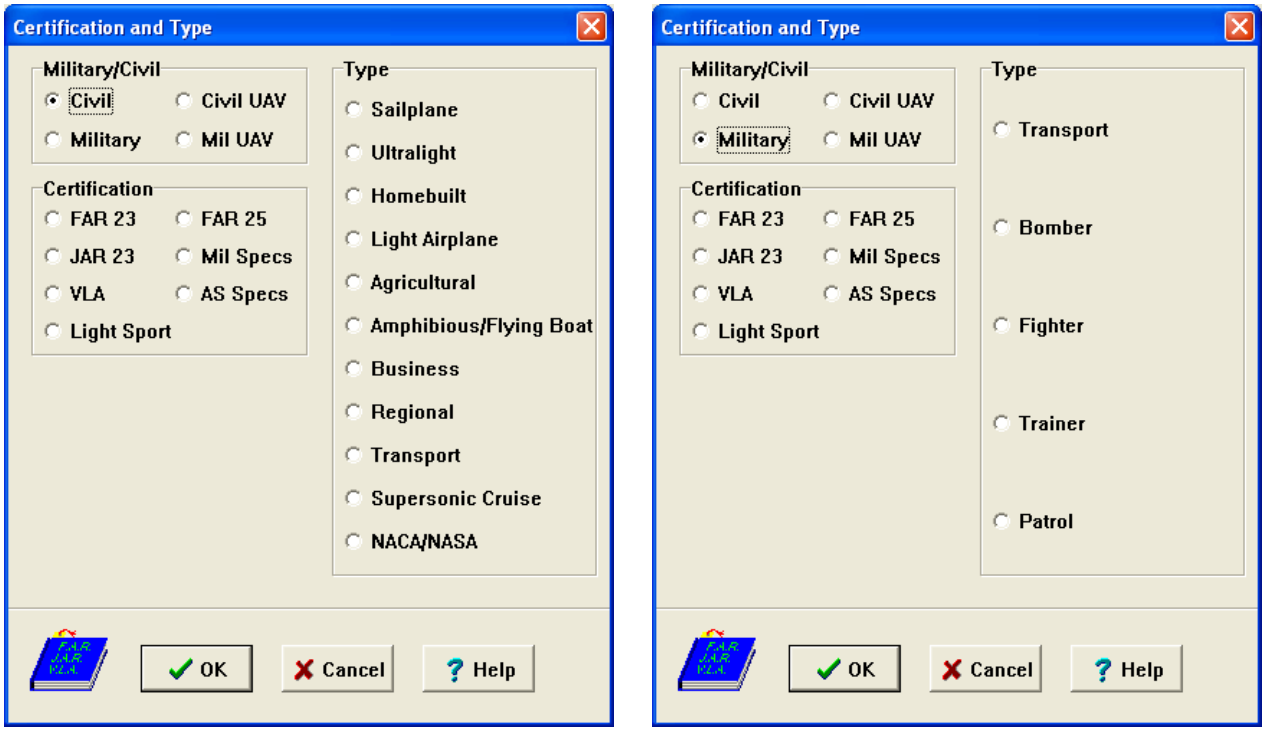


Figure 2.23 Certification and Type Dialog Box

The Certification and Type dialog box offers the user the following options for defining the aircraft categories:

- Military/Civil: The user can select from military or civil airplane types
- Type: Depending on the Military/Civil choice, the user can choose the airplane type
- Certification: The user can select the following certification standards:
  - FAR 23: Federal Aviation Regulations, Part 23
  - JAR 23: Joint Airworthiness Requirements, Part 23
  - FAR 25: Federal Aviation Regulations, Part 25
  - VLA: Very Light Aircraft
  - Mil Specs.: Military Specifications (MIL-F-8785C and MIL-STD 1797A)
  - AS Specs.: Naval Air Systems Command Specifications
  - Light Sport: Light Sport Requirements
- Category: Under FAR 23 or JAR 23, one of the following airplane categories can be defined:
  - Normal

- Utility
- Acrobatic
- Commuter

- Base: Under Mil Specs or AS Specs (not shown in Figure 2.14), the airplane base can be selected as land, carrier or both.

Classification Dialog Box

When the **Classification** button is selected, the Classification dialog box is displayed. Figure 2.24 shows the Classification dialog box. The airplane type classification for military flying quality evaluation can be specified. The regulations are used to evaluate flying qualities for both civilian and military airplanes.

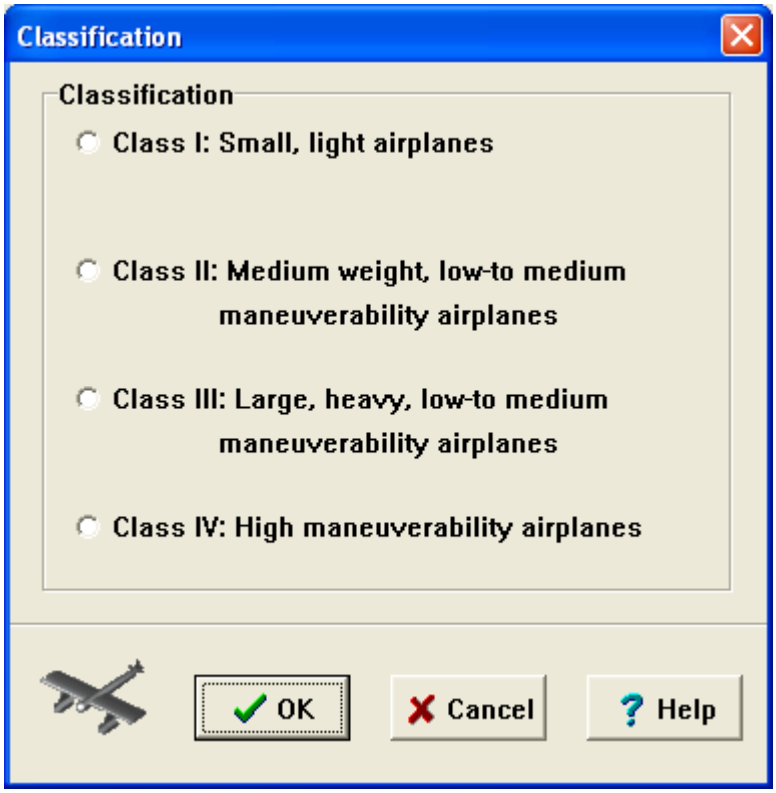


Figure 2.24 Classification Dialog Box

2.2.5 System Setup Toolbar

The System Setup toolbar (Figure 2.25) consists of seven bitmap buttons at the bottom of the main window. The System Setup toolbar buttons can be used to manage the program environment. The functionality of the buttons on the System Setup toolbar is described in Table 2.8.

Figure 2.25 System Setup Toolbar

Table 2.8 System Setup Toolbar Buttons

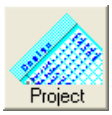
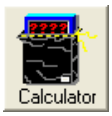
	Units: Select British or S.I. units for the input and output parameters.
	Date/Time: Select the date and time format in the status bar.
	**Project:** Specify the name of the project to be displayed in the status bar.
	Company: Specify the company name to be displayed in the status bar.
	Printer: Access the system print manager to define various printer attributes.
	**Calculator:** Select the calculator type: Standard or RPN.

Table 2.8 (Contd.) System Setup Toolbar Buttons

	Options: Select the size of the toolbar buttons. Choose whether parameter info and notes buttons are displayed on input/output elements (see Subsection 2.1.2). Choose whether to save WMF to file and specify the length of the recovery project auto-saving interval.

When the user selects Units on the System Setup toolbar, the Units Setup dialog box is displayed. The Units Setup dialog box is displayed in Figure 2.26. The program allows the user to work in the British or SI (Metric) system of units.

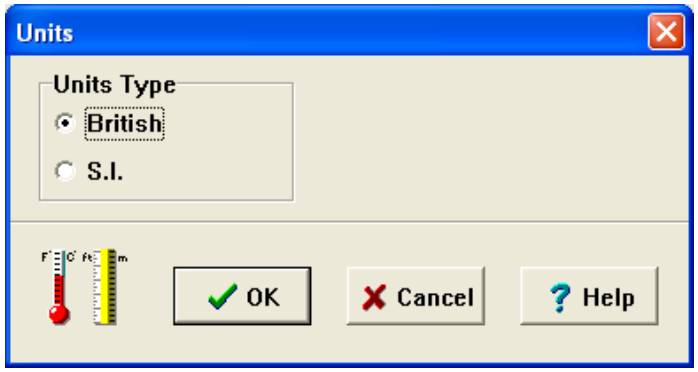


Figure 2.26 Units Setup Dialog Box

When the user selects Date/Time on the System Setup toolbar, the Date/Time Setup dialog box is displayed. The Date/Time Setup dialog box is displayed in Figure 2.27. The dialog box allows the user to choose the format of the date and time displays on the status bar.

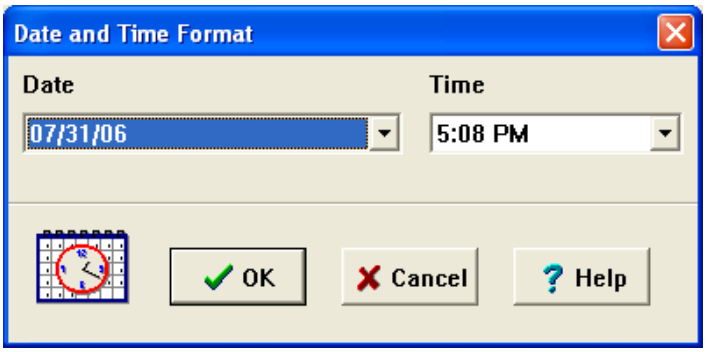


Figure 2.27 Date/Time Setup Dialog Box

When the user selects Project on the System Setup toolbar, the Project Name Setup dialog box is displayed. The Project Name Setup dialog box is displayed in Figure 2.28. The dialog box allows the user to specify a project name or other description, which will be displayed on the status bar.

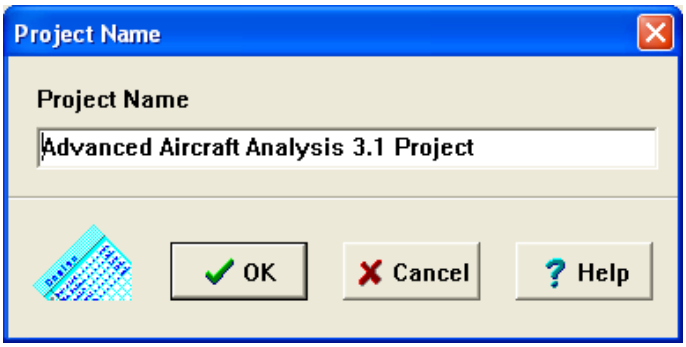


Figure 2.28 Project Name Setup Dialog Box

When the user selects Company on the System Setup toolbar, the Company Name Setup dialog box is displayed. The Company Name Setup dialog box is displayed in Figure 2.29. The dialog box allows the user to specify a company name or other description, which will be displayed on the status bar.

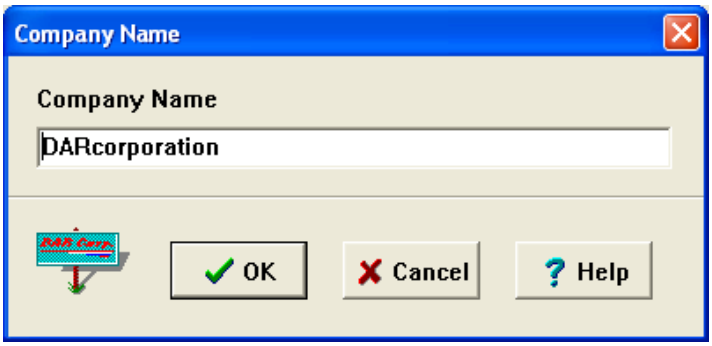


Figure 2.29 Company Name Setup Dialog Box

When the user selects Printer on the System Setup toolbar, the Print Setup dialog box is displayed. The Print Setup dialog box is displayed in Figure 2.30. The dialog box allows the user to specify the default printer and printer options used when printouts are generated.

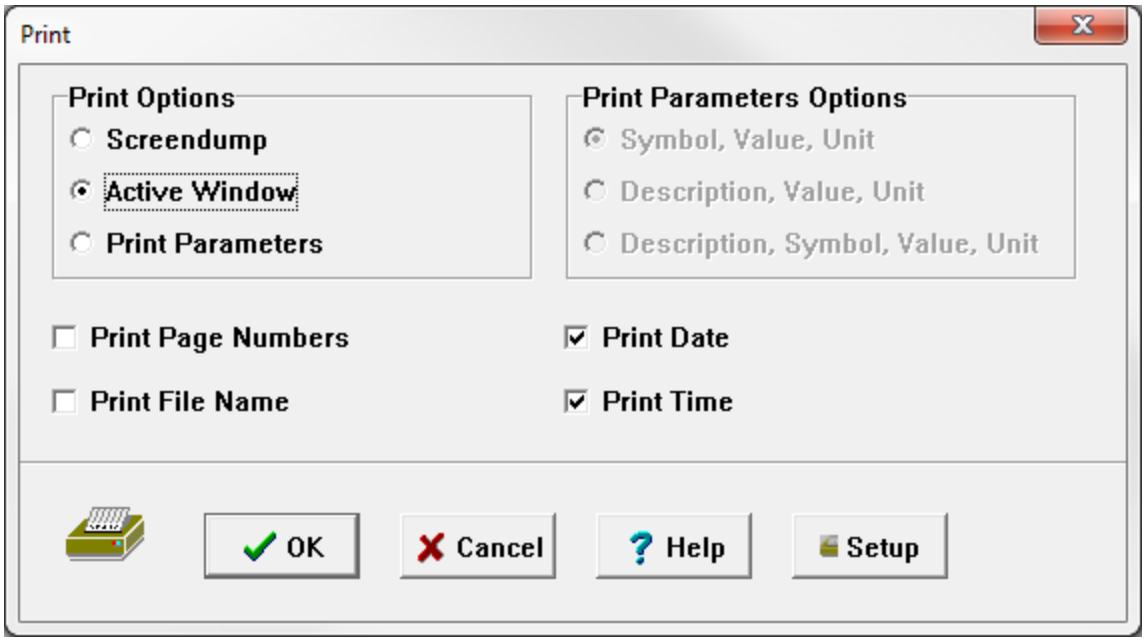


Figure 2.30 Print Setup Dialog Box

When the user selects Calculator on the System Setup toolbar, the Calculator Setup dialog box is displayed. The calculator is described in Section 3.2. The Calculator Setup dialog box is displayed in Figure 2.31. The dialog box allows the user to specify a standard or RPN calculator type.

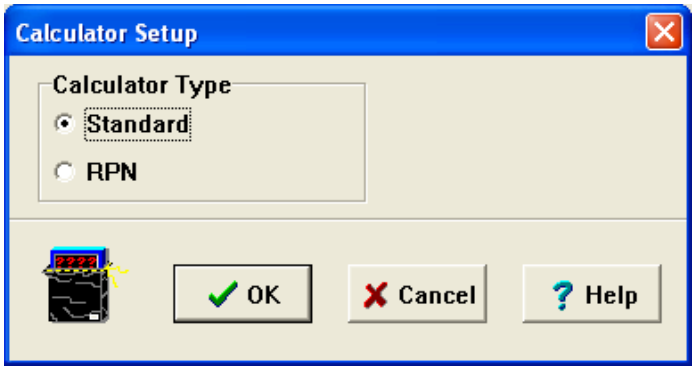


Figure 2.31 Calculator Setup Dialog Box

When the user selects Options on the System Setup toolbar, the Program Options dialog box is displayed. The Program Options dialog box is displayed in Figure 2.32. Descriptions of the dialog box functions follow.

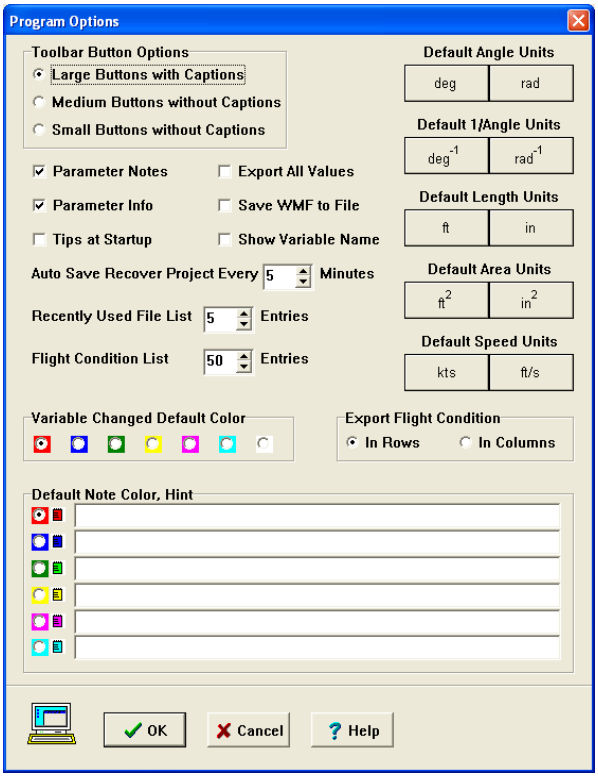


Figure 2.32 Program Options Dialog Box

- Toolbar Button Options: The user can choose from the three types of toolbar buttons, which will be displayed when the current project is opened. The button options are shown in Figure 2.32.
- Parameter Notes: The user can choose whether to switch on the parameter **Notes** button (see Figure 2.32).
- Parameter Info: The user can choose whether to switch on the parameter **Info** button (see Figure 2.32).
- Tips at Startup: The user can choose whether to have the tips show up at the start of the program (See Figure 2.32)
- Export All Values: The user can choose whether to export all values to ASCII.
- Save WMF to File: The user can choose whether to save the WMF graphics, created by using the **Copy WMF** button in the main toolbar (Figure 2.1), to a file.
- Show Variable Name: Displays the database variable name in the work pad dialog window.

- Auto Save Recovery Project: The default interval for auto-saving a recovery project is set to 5 minutes. Users can alter the interval according to individual preference. Detail on the recovery project is presented in Section 5.3.
- The Recently Used File List lets the user specify the number of recently used files that appear on the File menu.
- The Flight Condition List lets the user specify the number of flight conditions that appear in the Flight Condition drop-down menu in the Flight Condition dialog box.
- Default Note Color, Hint: This allows the user to define which color is the default when notes are entered for a variable. It also allows the user to associate a hint with each color to help identify certain stages of the design process.
- Variable Changed Default Color: This option allows the user to define which color the variables' backgrounds will change to if their values changes when the calculate button is used.
- Export Flight Condition: This option allows the user to export flight conditions to a spreadsheet either in rows or in columns.
- Default Angle Units: This allows the user to define whether degrees or radians will be the default angle unit throughout the project.
- Default 1/Angle Units: This allows the user to define whether $degree^{-1}$ or $radian^{-1}$ will be the default 1/angle unit throughout the project.
- Default Length Units: When British units are in use, this allows the user to define whether inches or feet will be the default length unit throughout the project. When S.I. units are in use, it allows the user to define whether millimeters or meters will be the default length unit throughout the project.
- Default Area Units: When British units are in use, this allows the user to define whether square inches or square feet will be the default area unit throughout the project. When S.I. units are in use, it allows the user to define whether square millimeters or square meters will be the default area unit throughout the project.
- Default Speed Units: This option allows the user to define the default speed unit as feet per second or knots.

2.3 Menu Bar

The main window menu bar is located at the top of the main window. Most options in the Menu Bar sub-menus have a corresponding option in the toolbars. The menu bar contains the File, Edit, Window and Help menus. The File menu contains nine options, which are described in Table 2.9.

Table 2.9 File Menu Options

File Menu Option	**Description**
New	Create a new project. Corresponds to the **New** icon on the File toolbar.
Open	Open an existing project. Corresponds to the **Open** icon on the File toolbar.
Save	Save the current project. Corresponds to the **Save** icon on the File toolbar.
Save As...	Save the current project under a different name or location. Corresponds to the **Save As** icon on the File toolbar.
Import	Import a supported file type (See subsection 2.3.1).
Export	Export a supported file type (See subsection 2.3.2).
Print...	Make a printout. Corresponds to the **Print** icon on the main toolbar.
Print Setup...	Set the default printer and printer options. Corresponds to the **Printer** icon on the System Setup toolbar.
Properties	Displays the various properties of the current project.
Exit	Exit the program. Corresponds to the **Exit** icon on the main toolbar.

The Edit menu options can be used after highlighting text in an edit box. The three options described in Table 2.10.

Table 2.10 Edit Menu Options

Edit Menu Option	Description
Cut	Delete the selected text and place in the Windows clipboard.
Copy	Copy the selected text into the Windows clipboard.
Paste	Paste the current text from the Windows clipboard into the edit box.

The Window menu options can be used to arrange application, input/output and plot windows within the main window. The three Window menu options are described in Table 2.11.

Table 2.11 Window Menu Options

Window Menu Option	Description
Tile	Size and arrange the open windows so that all of the windows can be seen on the screen.
Cascade	Arrange all of the open windows so that the title bar of each window can be seen.
Arrange All	If any windows are minimized within the main window, this option will arrange them at the bottom of the main window.

In addition, the Window menu displays a list of all open windows within the main window. Selecting a window name within the list will cause that window to be displayed and become active.

The Help menu options can be used to access the software help system and online manual. The five Help menu options are described in Table 2.12.

Table 2.12 Help Menu Options

Help Menu Option	Description
Help	Displays the help topic relating to the currently active window. This corresponds to the **Help** button on the main toolbar or the **Theory** button on the input/output window.
Online Help Manual	Displays the help on the internal layout of AAA, displays the support and services and description on how to use the online help.
Tip of the Day	Displays the tip of the day.
Using AAA Help	Displays the various help formats used in AAA.
What's New in AAA 3.2	Displays the WhatsNew32.pdf file.
e-mail Tech Support	Opens the user e-mail account to send an email to the tech support.
FAQ Online	Displays the DARcorporation Frequently Asked Questions web page.
Check for Updates	Checks the DARcorporation website for latest updates
About...	Displays a window describing the software version.

2.3.1 File Import

The following file types are supported for import into the software:

- Weight Table: Take-off vs. Empty Weight regression coefficient tables from AAA versions 1.0 through 1.7. These files have the extension "*.re".
- Geometry: Geometry parameter files for use in AeroPack. These ASCII files have the extension "*.geo".
- ASCII: Parameter files from the program ACE!IT, by Tecolote Research. These files have the extension "*.txt".

2.3.2 File Export

- Weight Table: Take-off vs. Empty Weight regression coefficient table. These files have the extension "*.rc".
- Geometry: Geometry parameter file for use in AeroPack. These ASCII files have the extension "*.geo".

- ASCII: Parameter file from the program ACE!IT, by Tecolote Research. These files have the extension “*.txt”.
- S&C Derivatives: ASCII formatted file containing all Stability and Control Derivatives and Data for all flight conditions of the current project. These files have the extension “*.txt”.

3 Input Devices for the Software

The following devices are used as input for the software: mouse, calculator, and keyboard. The devices are described in this chapter.

3.1 Operation of the Mouse and Cursor

The cursor usually appears as an arrow on the screen. The arrow will change to an hourglass shape while the software is auto-saving or during operations that take more time to perform. By moving the mouse on the desktop, the cursor can be moved to the desired position on the screen. The left mouse button is used to select all buttons in the program.

When the cursor is placed over an input/output element, it will change to a calculator. Also, a brief description, or hint, will be displayed for that element. The calculator can be displayed by clicking the left mouse button while the cursor is displayed as a calculator. The calculator is described in Section 3.2. When the cursor is placed over an edit box in an input/output element, it will change to a bar. If the left mouse button is clicked, and insertion bar will appear in the edit box, and the keyboard can be used to input a number.

3.2 Operation of the Calculator

The calculator pad is designed to minimize the use of the keyboard and to provide a user interface using a mouse. The calculator is activated (displayed on the screen) by clicking the left mouse button when the cursor appears as a calculator. The user may then use the calculator to input the value of the variable, or the user may instead choose to use the number keypad on the keyboard to enter the data. The calculator pad performs similar to an electronic calculator. The buttons are selected with the left mouse button. To deselect the calculator, close the calculator window using the system menu, or choose the Cancel button. A number will be entered in the software database when the **OK** button on the calculator or **<Enter>** on the keyboard is selected. The calculator is shown in Figure 3.1.

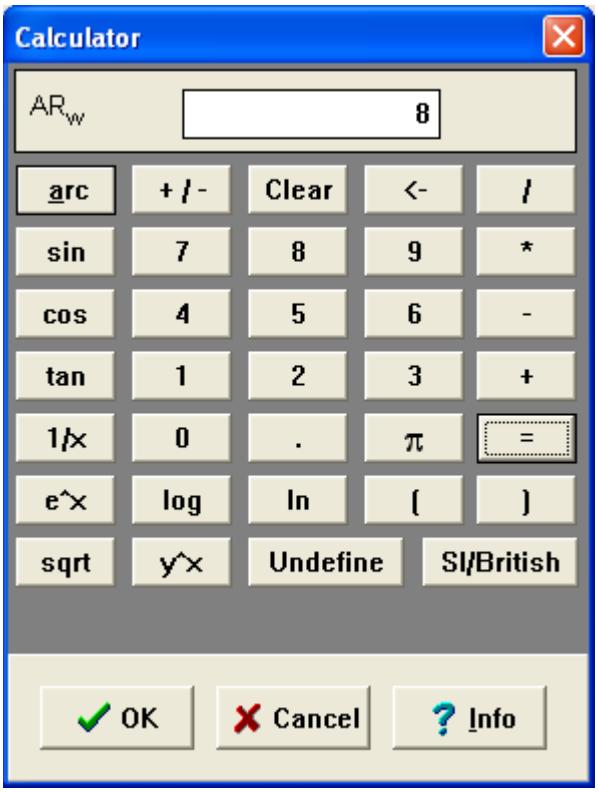


Figure 3.1 The Calculator

The calculator is equipped with special buttons. The functions of these special buttons are:

Info The **Info** button shows information about the current variable. The **Info** button always provides the user with the definition of the variable and, whenever possible, with a typical value or an approximate range for that variable. The user may select the typical value or range by moving the cursor to the line containing that value and pressing the left mouse button. The typical value will be entered into the calculator display, or a dialog box will appear allowing the user to choose a number within the suggested range. Some variable descriptions include a graph or diagram, which can be displayed by choosing "See Graphic".

Undefine The **Undefine** button allows the user to make a variable temporarily undefined. This button is designed for those cases where the user has the intention of removing the parameter for the calculation but not from the database. To restore the value of the parameter, invoke the calculator and press the **OK** button. An undefined variable appears blank in the input/output parameter.

Clear Selecting this button will erase the current number from the calculator display. In case the current number replaced an old number, the old value will appear. The number will not be cleared in the database.

SI/British Selecting this button will cause the displayed unit to switch between the British and SI units. The displayed value will also be converted to the selected unit. In the input/output element, the value will be shown in the units set during the software installation or with the **Units** button in the System Setup toolbar.

3.3 Keyboard

The keyboard can be used in the software when the user is prompted for text input within a dialog window, entering a number once the calculator is displayed, or entering data directly into an input/output element. If the keyboard is used to enter data directly into an input/output element, selecting the **<Enter>** or **<Tab>** key will enter the currently displayed number into the database, and move the cursor to the next element in the input or output group. Keyboard shortcuts exist for the Calculate and Close icons found in the input/output windows. The **<F9>** key will perform the calculation, and **<F4>** will close the active input/output window.

3.4 System Messages

There are two types of messages, which warn the user of possible pitfalls in the design process or demonstrate methods of performing certain actions. The first type of message is informative. The second type of system message is automatically given by the system. These messages usually contain critiques of user input. These contain warnings or guidelines. The user still has the option to ignore such warnings or guidelines. However, in the case where such an act could lead to a mathematical problem (i.e. divide by zero), the system ignores the user's request.

3.5 Flexible Input

One of the features of the program is the capability to bypass certain computation sequences. The software is designed to ignore the computation sequence and make use of user defined values instead. This feature is not always available and should be used with caution. Using this feature demands a clear understanding of the computation sequence in the application module.

For example:

I - A, B and C are input values into the calculation module

II- D and E are output values of the calculation module

III- D is calculated by: D = f(A,B)

IV- E is calculated by: E = f(C,D)

In a normal case, the user provides all input values (A, B and C) and the application module calculates the output parameters (D and E) with equation III and IV. Consider the case where the user does not want to calculate D from equation III but wishes to provide his/her own value and still wants to use the system logic to calculate E. To do this, it is sufficient to define the C value in the input group and the desired D value in the output group. The A and B values should be left undefined. If A and B are already defined, they should temporarily be made undefined by using the **Undefine** button on the calculator described in subsection 4.2. When the user clicks the **Calculate** button on the input/output window command bar, the system checks all the variables in the input group. Since A and B are undefined, the program logic ignores the part related to the calculation of D. Then it checks the database for the required parameters for calculation of E. In this case, it will find that D and C are given and E can be calculated from equation IV. In this example, the system ignores its internal logic to calculate D and gives authority to the user to supply the desired D value.

4 Generating Hardcopy Output

Hardcopy output in the software can be in one of the following forms:

- **Screendump**: This is performed by clicking the Print button on the main toolbar and selecting the **Screendump** option in the Print dialog box (See Subsection 2.2.1). When the **OK** button is clicked, a bitmap representation of the main window is sent to the default printer. The print may take one or two minutes on slower printers.
- **Active Window**: This is performed by selecting the **Active Window** option in the Print dialog box (see Subsection 2.2.1). This option is only available when an application window, input/output window or plot window is open within the main window. When the **OK** button is clicked, a representation of the active window is sent to the default printer. This option is faster than the **Screendump** option.
- **Print Parameters**: This is performed by selecting the **Print Parameters** option in the Print dialog box (See Subsection 2.2.1). Once print parameters is selected, the user is prompted with the three options on the format of the output file (See Subsection 2.2.1). Table 5.1 lists the resultant output for the three options.

Table 4.1 Resulting Output for the Three Formatting Options in Print Parameters

Print Parameters Option	Resulting Output
Symbol, Value, Unit	Advanced Aircraft Analysis Project **Straight Tapered Wing Geometry** AR_w = 10.00 S_w = 500.00 ft^2 λ_w = 0.40 $\Lambda_{C/4_w}$ = 25.0 deg

Table 4.1 Resulting Output for the Three Formatting Options in Print Parameters (Contd.)

Description, Value, Unit	Advanced Aircraft Analysis Project **Straight Tapered Wing Geometry** Wing Aspect Ratio = 10.00 Wing Area = 100.00 ft^2 Wing Taper Ratio = 0.40 Wing Quarter-chord Line Sweep Angle = 0.000 deg
Description, Symbol, Value, Unit	Advanced Aircraft Analysis Project **Straight Tapered Wing Geometry** Wing Aspect Ratio AR_w = 10.00 Wing Area S_w = 100.00 ft^2 Wing Taper Ratio λ_w = 0.40 Wing Quarter-chord Line Sweep Angle $\Lambda_{C/4_w}$ = 0.000 deg

5 Software Databases and Projects

The system features a database structure to store and retrieve airplane design and analysis project parameters. Two types of databases are used. The first type of database is fixed and used by the program to retrieve information that does not change with use of the program. The first type of database is discussed in Section 5.1 and 5.2.

The second type of database is used to store parameter values and characteristics that change with use of the program. A project consists of a collection of this type of databases. Projects and their individual databases are described in Section 5.3.

5.1 The System Database

The system database is used to store information about parameters that do not change. The system database is located in the folder <dar folder>\Database where <dar folder> is the folder where the software is installed. The system database should never be deleted or modified in any way. The system database stores the following information about every numeric parameter used in the software:

- Name of the variable
- Engineering Symbol of the variable
- Name of the info topic for the variable
- Conversion factor between British and SI units
- Number of decimal places to display for the variable
- Minimum allowable value for the variable
- Maximum allowable value for the variable
- Short definition of the variable that is displayed as described in Figure 2.3.

5.2 File Compatibility with Previous Versions

Files created with AAA versions 1.0 through 2.4 and other airplane design software by DARcorporation can be opened with this version of the software. The file can then be saved as a

project in this version. This version does not support saving projects as files for use with previous versions. Files saved with Unix versions (1.0 through 1.7) of AAA can be opened by choosing the '.ana, .analys' option in the **Files of Type** box in the File Open dialog box described in Subsection 2.2.2.

5.3 Projects and Their Databases

A project consists of a project file and multiple databases for flight conditions and airplane components. While the software is running, the current project is stored in the folder <dar folder>\Working, which is called the Working Directory. When the software is started with a new project, the default name is project1. The new project is kept in the Working Directory until it is saved for the first time. When the project is saved, all of the files in the Working Directory are copied into one AAA project file specified by the user in the Save As dialog box (see Subsection 2.2.2). Projects can be moved by using the **Save As** button in the File Management toolbar or the **File/Save As** menu command.

When an existing project is opened, the project is first copied to the Working Directory where it is used by the program. When the user saves the project, it is copied from the Working Directory back into its original folder. The program has been set to automatically save the recovery file in the Working Directory every 5 minutes. The user can alter the interval in the Program Options dialog box (Figure 2.29).

When the software is exited normally, the contents of the Working Directory are cleared. If the software exists abnormally due to a program or system crash, the current project will remain in the Working Directory. The next time the program is started, it will attempt to recover the contents of the Working Directory as a recovery project. It is strongly recommended that the user save the recovered project as a new project until it is confirmed that the recovery was successful and complete.

Warning:

The Working Directory should be reserved for use only by the software. The user should not attempt to save projects or copy files from other locations to the Working directory.

6 Help System

The Help system is an online system of help topics that give the user information about the use of the program and the theory and definitions behind the calculations. The online help system can be accessed in six ways:

- Select the User's Manual icon in the Airplane Design and Analysis Program group.
- Select the **Help** button on the main toolbar (see Subsection 2.2.1).
- Select an item in the **Help** menu on the main window menu bar (see Section 2.3).
- Select the **Info** button on the calculator or any other dialog that includes a **Help** button.
- Select the **?** button on an input/output element
- Select the **Theory** button on an input/output window

The online help system consists of three types of help topics. The three types of help topics and the method of accessing them are described in the following sections:

6.1. User's Manual topics

6.2. Variable Info topics

6.3. Theory topics

6.1 User's Manual Topics

These topics describe the functionality of the various windows, toolbars and dialog boxes described in Chapter 2 of this part of the User's Manual. These topics can be accessed in the following ways:

- When there are no application, input/output or plot windows open in the main window, select the **Help** button on the main toolbar (see Subsection 2.2.1).
- When there are no application, input/output or plot windows open in the main Window, select an item in the **Help** menu on the main window menu bar (see Section 2.3).
- Select the **Help** button on any dialog.

6.2 Variable Info Topics

Every variable that is displayed in an input/output element (see Subsection 2.1.2) has a topic that defines that variable. Whenever possible, typical values for the variable and a graphical depiction of the variable are shown in the variable info topic. The variable info topic can be displayed in two ways:

- Select the **Info (?)** button on the input/output element. If the **Info (?)** button is not visible on the input/output element, the **Options** button on the System Setup toolbar (see Subsection 2.2.4) can be selected to change the input/output elements display properties.
- Select the **Info** button on the calculator (see Section 3.2).

6.3 Theory Topics

Every calculation module of the software has a theory topic, which explains the methods behind the calculation. The theory topic can be displayed in two ways:

- Select the **Theory** button on the command bar of the input/output window.
- Select the **Help** button on the main toolbar (see Subsection 2.2.1) when the calculation module's input/output window is open and active.

PART II

Application Modules

This part describes the function and use of the application modules. The application modules are based on References 1 through 12.

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1 Weight Module

1.1 General Description

The purpose of this module is to estimate airplane component weights and to determine whether or not the center of gravity of the airplane is within the desirable range for different loading and unloading scenarios. The methods are based on Chapter 2, Sections 2.1 to 2.5 and Section 2.7 of Reference 1, Chapter 10 of Reference 2, and Chapter 2 of Reference 5. This module also contains the moments of inertia calculation, based on Chapter 3 of Reference 5. Use of the Weight module options will be described in the following sections.

1.2 Weight Main Window

After invoking the **Weight** module, 3 options are displayed:

- **Weight Sizing** The options provided in this module are discussed in Section 1.3.
- **Class I Weight** The options provided in this module are discussed in Section 1.4.
- **Class II Weight** The options provided in this module are discussed in Section 1.5.

1.3 Weight Sizing

The purpose of the Weight Sizing submodule is to rapidly estimate the following weight components and/or sensitivity coefficients:

- Take-off weight, W_{TO}
- Empty weight, W_E
- Mission fuel weight, W_F
- Sensitivity of take-off weight to aerodynamic, propulsion and mission parameters

These parameters are estimated on the basis of the following inputs:

- A mission specification (optional)
- Statistical relations between empty weight and take-off weight of existing airplanes.

Once this selection has been made, a new menu appears with six options. The six options displayed are:

1.3.1	Mission Profile	Allows the user to calculate the overall mission fuel fraction by entering the flight segments from the start to the end of the mission.
1.3.2	Take-off Weight	Calculates mission fuel weight, take-off weight and empty weight. A plot showing the iteration process is provided.
1.3.3	L/D from Weights	Calculates the climb, cruise, turn and loiter lift-to-drag ratios, based on corresponding segment weights. It iterates between Weight Sizing and Class I Drag (since the wetted area is calculated from take-off weight) to obtain a converged solution for the take-off weight.
1.3.4	Regression	With this option, the user can enter statistical data by providing empty weights and take-off weights in a table and calculate the regression coefficients A and B. A logarithmic plot of the entered data is also provided.
1.3.5	Sensitivity	After performing Mission Profile and Take-off Weight, sensitivities of take-off weight for changes in aerodynamic, propulsion and mission parameters can be calculated.
1.3.6	Useful Load	This module calculates the range for different payload scenarios starting with a minimum of 1 pilot and ending with the maximum payload specified in the Take-off Weight module.

1.3.1 Mission Profile

This option shows the Segment Input and Fuel-Fraction Calculation menu. This menu consists of four command buttons:

- **New Segment** — This command is used to enter a new segment of the mission specification. A selection can be constructed from the twelve mission segments. The newly specified flight segment is added at the end of the previously defined segments. After choosing the desired segment, an input/output window is displayed. For some flight segments, the **Calculate** button must be selected to get the fuel-fraction. For other segments, the input will be the fuel-fraction. The selected mission segment will be displayed in a table together with the fuel-fraction for this segment.
- **Delete Segment** — With this command, a segment can be deleted from the flight profile. The user selects a segment that is to be deleted. All data related to this segment will be erased. If the user wishes to exit without deleting a segment, any menu can be selected to exit this command.
- **Insert Segment** — With this command, a flight segment can be inserted between two previously entered segments. When the **Insert Segment** command is selected, a menu with twelve flight segments as described in **New Segment** will appear. Upon selection of a new segment to be inserted, the user must select the position of the new segment within the mission profile. The new segment will be inserted before the segment selected as the new position. Inserting at the end of the table is possible by selecting **New Segment** instead of **Insert Segment**. To cancel insert segment, select any button in another menu.
- **Move Segment** — A segment in the mission profile table can be moved to another location by selecting it and selecting the flight segment after which

it is to be inserted. If the user wishes to exit without moving a segment, select any menu to exit this command.

Input data in a particular flight segment can be changed by selecting the flight segment from the previously created table.

1.3.2 Take-off Weight

This command is used to calculate the airplane take-off weight from the mission segment fuel fractions and regression coefficients. Once **Take-off Weight** is selected, a display of all mission segments, previously generated in **Mission Profile**, will appear together with an input and output group. The regression coefficients A and B can either be entered in the input section or calculated after invoking **Regression**. After entering all input data and selecting **Calculate**, the empty weight, take-off weight, mission fuel weight, used fuel weight, mission fuel fraction, fuel burned in each flight segment and the fuel available and airplane weight at the beginning of each flight segment will be calculated and displayed.

The calculation leads to one of the following cases:

1. No solutions for take-off weight
2. One solution for take-off weight
3. Two solutions for take-off weight

The mathematical background for the above stated scenarios can be found in Appendix A of Reference 1. A plot function is available to show the iteration process used to arrive at these solutions. For case 1, the input data must be changed to obtain a solution. For case 2, no modifications are necessary. If case 3 occurs, the program automatically chooses the lowest weight solution.

1.3.3 L/D from Weights

This command calculates the climb, cruise, turn and loiter lift-to-drag ratios, based on

corresponding segment weights. It iterates between Weight Sizing and Class I Drag (since the wetted area is calculated from take-off weight) to obtain a converged solution for the take-off weight.

1.3.4 Regression

This command is used to calculate the regression coefficients, A and B, by supplying empty weights and take-off weights of actual airplanes in a table. This option allows the user to generate a table of empty weights and take-off weights. The number of take-off and empty weight combinations (maximum 50) is first specified. An empty table will appear with one column each for the airplane name, take-off weight and empty weight. When all input data are entered, and the user selects **Calculate**, this will calculate the intercept A and slope B for a logarithmic relation between take-off and empty weight using a least squares method. Increasing the number of input parameters adds an empty row at the end of the table, which allows for the addition of a data point to be used in calculating A and B. The maximum number of rows is 50. This command can also be used to delete table rows from the bottom of the table.

After creating or loading a table (use the **Import** option in the **File** menu), the data can be plotted with a logarithmic scale (A and B must be calculated first). The standard plot options are described in Chapter 2 of Part II of this manual. If the take-off weight and empty weight of a design have been calculated using the **Take-Off Weight** option, they will be plotted with the weight table elements and be designated by a Design Point label.

1.3.5 Sensitivity

This option allows the user to calculate the sensitivity of take-off weight to aerodynamic, propulsion and mission parameters. Once all data from **Mission Profile** and **Take-Off Weight** are available, selecting **Calculate** will display take-off weight sensitivities with respect to payload weight and empty weight. The results are shown in a table, which will appear with the flight segments and the corresponding weight sensitivities.

1.3.6 Useful Load

This module calculates the range for different payload scenarios starting with a minimum of 1 pilot and ending with the maximum payload specified in the Take-off Weight module.

1.3.7 Remarks

1. The payload weight excludes expended payload such as bombs and ammunition. Payload dropped during the mission has to be specified in the **Mission Profile**. Payload, which is not dropped, must be included in payload and crew weights.
2. Refueled fuel weight during the mission must be specified in the **Mission Profile**.
3. A change in expended payload and refueled fuel can only be made in the **Mission Profile** submodule since the location of the payload expenditure and refueling segment in the flight profile is essential for the calculation of the weights.

1.4 Class I Weight

The **Class I Weight** module consists of four separate submodules. After invoking **Class I Weight**, a menu appears with the following options:

1.4.1 **Weight Fractions** With this option, the user can determine the aircraft component weights by using the weight fraction methods.

1.4.2 **Center of Gravity** This option allows the user to calculate the airplane empty and current weights and center of gravity locations.

1.4.3 **Inertia Estimate** With this option, the user can calculate the airplane moments of inertia with radii of gyration methods.

1.4.4 **Radii of Gyration** With this option, the user can calculate the airplane radii of gyration method using airplane moment of inertia methods.

1.4.1 Weight Fractions

This option allows the user to calculate component weights by using the weight fractions method. The data can be provided by the user, or the AAA database of comparable airplanes can be used. After selecting an airplane category, the user may select airplanes available in that particular

category. One or more airplanes can be selected. Because the Class I component weight estimation is based on the selected aircraft, the user should choose the most comparable aircraft. To deselect an airplane, select the airplane from the current selection list and remove it.

The Class I Weight Fractions component contains the options **Add Airplane**, **Select Airplane**, **Fractions** and **Weights**, which have the following functions:

- **Add Airplane** — Allows the user to add new airplanes to the already available airplanes appearing in the table. The user has to supply the weight fraction data. This data will automatically be added to the **Select Airplane** menu under the Airplane Category labeled "User Defined."
- **Select Airplane** — Allows the user to select existing airplanes from the program database for use in the Class I component weight estimation. All the available airplanes in all categories can be displayed. The user may select any combination of these to use in the weight estimation by adding them to the current selection list.
- **Fractions** — After selecting one or more airplanes, this button will show the weight fraction data of the selected airplanes. By pressing **Calculate**, the average weight fractions will be calculated. If a weight component fraction for a selected airplane is not available, the representative box will be blank, and this component will not be used in determining the average. By scrolling down the list, the remaining selected airplane data can be shown in case they did not appear on the current screen.
- **Weights** — Input and output menus will appear. In this menu, the Class I component weight estimation is completed. The estimation is based on the calculated average weight fractions. By selecting **Calculate** the estimated component weights will be displayed. When the calculated empty weight does not match the user supplied empty weight calculated in **Weight Sizing**, an adjustment is

made which is distributed over all items in proportion to their component weight values listed in the last column.

1.4.2 Center of Gravity

This option allows the user to calculate the airplane center of gravity by entering weight components and their locations in a preformatted table. The **Center of Gravity** module consists of three separate submodules. After invoking **Center of Gravity**, a menu appears with the following options:

- **Empty Weight** — With this option, empty weight components and the associated center of gravity coordinates can be tabulated. The center of gravity of the empty airplane will be computed using only the components for which all data is supplied. This option will be described in Section 1.4.2.1.
- **Total C.G.** — With this option, the Center of Gravity Location of the airplane can be calculated for the specified loading scenario.
- **C. G. Excursion** — This option allows the user to generate graphs displaying the calculated center of gravity excursion in the X-, Y- and Z-directions. This option will be described in Section 1.4.2.2.

1.4.2.1 Empty Weight

This option allows the user to calculate the airplane empty weight and associated center of gravity location. This module consists of two different submodules. The first one, **From Fractions**, uses the weight components previously calculated in the **Weight Fractions** module. The second one, **Detailed**, is divided into the following four options:

- **Structure** — With this option, the user can tabulate the structure weight components and center of gravity coordinates. The overall weight and center of gravity of the structure will be calculated using only the components for which all data is supplied. If a component weight and center of gravity location has been entered in the **From**

Fractions Empty Weight Table, their values will automatically be entered in the Structural Weight Table.

- **Powerplant** — With this option, the user can tabulate powerplant weight components and the associated center of gravity coordinates. The overall weight and center of gravity of the powerplant will be calculated using only the components for which all data is supplied. If a component weight and center of gravity location has been entered in the **From Fractions** Empty Weight Table, their values will automatically be entered in the Powerplant Weight Table.
- **Fixed Equipment** — With this option, the user can tabulate fixed equipment weight components and the associated center of gravity coordinates. The overall weight and center of gravity of the fixed equipment will be calculated using only the components for which all data is supplied. If a component weight and center of gravity location has been entered in the **From Fractions** Empty Weight Table, their values will automatically be entered in the Fixed Equipment Weight Table.
- **Empty Weight** — The results from the **Structures**, **Powerplant** and **Fixed Equipment** submodules described above are used to calculate the airplane current weight and center of gravity coordinates.

1.4.2.2 C.G. Excursion

This option allows the user to specify a component weight loading/unloading scenario. Loading starts from the empty weight of the airplane and successively adds weight components to the airplane until the maximum take-off weight is reached. At each step, the new location of the airplane center of gravity is calculated and stored. This procedure is repeated for the unloading case with the starting point at the maximum take-off weight. Mission loads and fuel are successively subtracted from the airplane weight according to the unloading scenario until the empty weight is reached. Each component (1 up to 13) can be used only once in each of the

loading/unloading columns of the table. Once the loading scenario is provided and the center of gravity travel is calculated, the C.G. excursion diagrams in the X-, Y- and Z-directions can be displayed with the **Plot** selection.

1.4.3 Inertia Estimate

This option allows the user to estimate the moments of inertia of the airplane with the radii of gyration method. The user can provide the data or the preloaded database can be used. The user has the option to select data from comparable airplanes. By selecting a category, a choice can be made between several available airplanes appearing in a table. Because the Class I inertia estimation is based on the selected aircraft, the user should choose the most comparable aircraft. The user may add an airplane more than once to weigh the importance of a particular configuration. To deselect an airplane, the user can remove the airplane from the current selection list. The Inertia Estimation module contains the options **Add Airplane**, **Select Airplane** and **Moment of Inertia**, which will be explained here.

- **Add Airplane** — Allows the user to add inertia data for new airplanes to the already available airplanes appearing in the table. The user has to provide the data for the Radius of Gyration Table. This data is automatically added to the **Select Airplane** menu under the Airplane Category labeled User Defined.
- **Select Airplane** — Allows the user to select existing airplanes from the program database for use in the Class I moment of Inertia estimation. All the available airplanes in all categories can be displayed. The user may select any combination of these to use in the Inertia estimation by adding them to the current selection list.
- **Moment of Inertia** — After selecting one or more airplanes, this button will display an input/output window. The average radii of gyration are already calculated and will be shown in the input section. If data are not available, these airplane radii of gyration are not used in averaging. The user needs to supply the remaining data and select **Calculate** to generate the moments of inertia.

1.4.4 Radii of Gyration

This option allows the user to estimate the radii of gyration of the airplane using moment of inertia values. The user provides the inertia data, gross weight, span and length, and the radii of gyration are calculated for each of the three axes.

1.5 Class II Weight

The purpose of this module is to present a Class II method for estimating airplane component weights. The Class II estimation methods used in this module are based on those described in Reference 5 and Reference 6. These methods employ empirical equations that relate component weights to airplane design characteristics. In the **Class II** weight estimate module, the weight estimation methods are identified as follows:

- Cessna method
- USAF method
- General Dynamics (GD) method
- Torenbeek method
- Vought method

The different weight component estimation options will be discussed in Section 1.5.1 through 1.5.4. Because airplane component weight modeling in the AAA program is a function of the airplane take-off weight, W_{TO}, the Class II weight estimation is an iterative process. The weight iteration process will be discussed is Section 1.5.5.

After selection of **Class II Weight**, the program will choose a weight estimation category based on the user supplied airplane certification, type and powerplant specifications.

The Aircraft Weight Components menu will be displayed next with the following options:

1.5.1 **Structure** To estimate the airplane structure component weights.

1.5.2 **Powerplant** To estimate the airplane powerplant component weights.

1.5.3 **Fixed Equipment** To estimate the airplane fixed equipment component weights.

1.5.4 **User Weight** To estimate the user defined weights.

1.5.5 **Total Weight** To calculate the take-off weight.

1.5.6 **Weight Iteration** To estimate the airplane take-off weight by iteration of structure, powerplant and fixed equipment component weights.

1.5.7 **Center of Gravity** To estimate the airplane weight and center of gravity location for the specified loading scenario.

1.5.8 **Inertias** To estimate the airplane moment of inertia about the body axis.

1.5.9 **Set Category** To select a different airplane category.

1.5.1 Structure Component Weight Estimation

The airplane structure weight consists of the following components: wing, empennage, fuselage, landing gear and nacelles. In this module, the structure component weights can be estimated with the available methods described in Reference 5. The structure weight components menu consists of the following options:

- **Wing** To estimate wing weight for strut braced or cantilever wings.
- **Horizontal Tail** To estimate the horizontal tail weight.
- **Vertical Tail** To estimate the single or twin vertical tail weight.
- **V-Tail** To estimate the v-tail weight.
- **Canard** To estimate the canard weight.
- **Fuselage** To estimate the fuselage weight.
- **Tailboom** To estimate the tailboom weight.
- **Nacelle** To estimate the nacelle weight.
- **Landing Gear** To estimate the landing gear weight.
  - **Nose Gear** To estimate the nose gear weight.
  - **Main Gear** To estimate the main gear weight.
  - **Tail Gear** To estimate the tail gear weight.
  - **Outrigger Gear** To estimate the outrigger gear weight.
  - **Total Gear** To estimate the total gear weight.
- **Total Structure** To calculate the total structure weight.

1.5.2 Powerplant Component Weight Estimation

The airplane powerplant weight consists of the following components: engines, air induction system, propellers, fuel system and propulsion system. In this module, the powerplant component weights can be estimated with the methods of Reference 5. The powerplant weight components menu consists of the following options:

- **Propeller** — To estimate propeller weight. This option is only available for piston, turboprop and propfan engines.
- **Engine** — To estimate engine weight. The engine weight includes engine, exhaust, cooling, supercharger, afterburners, thrust reversers and lubrication systems.
- **Fuel System** — To estimate fuel system weight.
- **Air Induction** — To estimate air induction weight. The air induction component weight includes inlet ducts other than nacelles, ramps, spikes and associated controls.
- **Propulsion Syst.** — To estimate propulsion system weight. The propulsion system weight components include engine controls, starting systems, propeller controls and provisions for engine installation.
- **Total Powerplant** — To estimate total powerplant system weight.

1.5.3 Fixed Equipment Component Weight Estimation

In this module, the fixed equipment component weights can be found with the methods of Reference 5. The fixed equipment weight components menu consists of the following options:

- **Flight Control** — To estimate the weight of the flight controls systems.
- **Hydr/Pneum Syst** — To estimate the weight of the hydraulic and pneumatic systems.
- **Instr/Avion/Elec** — To estimate the weight of the instruments, avionics and electronics. The weight estimation in this module is obsolete for modern EFIS type cockpit installations and for modern computer based flight management and navigation systems.
- **Electrical Syst.** — To estimate the weight of the electrical systems.

- **Airc/Press/Icing** To estimate the weight of the air-conditioning, pressurization and anti- or de-icing systems.
- **Oxygen Systems** To estimate the weight of the oxygen systems.
- **Auxiliary Power** To estimate the weight of the auxiliary power unit.
- **Furnishings** To estimate the weight of the furnishings.
- **Baggage/Cargo** To estimate the weight of the baggage and cargo handling equipment.
- **Operational Items** To estimate the weight of the operational items.
- **Armament** To estimate the weight of the armament. This option is not available for General Aviation or Commercial airplanes.
- **Weapon Provision** To estimate the weight of the guns, launchers and weapon provisions. This option is not available for General Aviation or Commercial airplanes.
- **Other Items** To estimate the weight for other, not previously tabularized weight items.
- **Total Fixed Equip.** To estimate the total fixed equipment weight.

1.5.4 User Weight Estimation

The user defined weights for components that are not listed in the Structure Weight, Fixed Equipment Weight or Powerplant Weight modules, are estimated in this module.

1.5.5 Total Weight Estimation

The **Total Weight** submodule allows the user to estimate the airplane take-off weight. This take-off weight is used in the first step of the take-off weight iteration process and is defined as:

$$W_{TO} = W_{structure} + W_{pp} + W_{fix} + W_{PL} + W_{PL_{\exp}} + W_F + W_{F_{refuel}} + W_{tfo}$$

$$W_F = \left(1 - M_{ff}\right)\left(1 + M_{F_{res}}\right)W_{TO}$$

$$W_{tfo} = M_{tfo} W_{TO}$$

Where:

W_{TO} Airplane take-off weight in [lb] or [N]

$W_{structure}$ Airplane total structure weight in [lb] or [N]

W_{pp} Airplane total powerplant weight in [lb] or [N]

W_{fix} Airplane total fixed equipment weight in [lb] or [N]

W_{PL} Airplane payload weight in [lb] or [N] (includes weight of crew)

$W_{PL_{\exp}}$ Expended payload weight in [lb] or [N]

W_F Airplane mission fuel weight in [lb] or [N]

$W_{F_{refuel}}$ Refueled fuel weight in [lb] or [N]

W_{tfo} Weight of trapped fuel and oil in [lb] or [N]

M_{ff} Mission fuel fraction

$M_{F_{res}}$ Reserve fuel weight as fraction of fuel weight used in the mission in [%]

M_{tfo} Trapped fuel and oil weight as a fraction of take-off weight in [%]

Instead of reentering the calculated take-off weight in the individual component weight calculations, and estimating the take-off weight within a given accuracy, the user can perform the iteration in the weight iteration submodule as discussed in Section 1.5.5.

1.5.6 Weight Iteration Process

The **Weight Iteration** submodule allows the user to perform the take-off weight iteration with an accuracy of 0.05 lb. Once all required input is defined, the iteration table will be displayed. If not all the input parameters are defined, a message will be displayed indicating the missing weight component input data. The error may be a result of undefined data in the **Class II** Weight estimation menus or weight fractions not defined in the **Class I** Weight estimate submodule. The **Class II** Weight input can be defined in the **Structure**, **Powerplant**, and **Fixed Equipment** Weight Estimation submodules. The Class I weight fractions can be estimated in the **Class I Weight** estimation module after selection of the **Weight Fraction** option.

The iteration table consists of an input group and a component weight table. The 'hashed' cells in the table indicate that weight estimation methods are not available for the specific weight component for the specific airplane category or engine type. All other cells, except the last column, which represents the average weights, represent a weight component for a specific weight estimation method and can be deselected. Deselecting a component in the table will cause that specific component to not be used in the weight Class II iteration process.

The user can deselect a method by undefining the specific box (delete the input from the corresponding cell in the table). When the iteration process is activated by selecting the **Calculate** button, all blank cells will not be included in the iteration. The estimated take-off weight will be displayed below the iteration table. To include an estimation method that has been deselected, type any number in the corresponding box. When the **Calculate** button is selected, that method will be included in the iteration.

The weight iteration component weight table contains a W_{user} column. This column can be used to fix the weight of a specific component. The column can also be used to influence the average weight of a component. To fix the weight of a component, enter the known weight in the W_{user} column, and delete the contents of the other estimation method cells for the component. To influence the average, leave one or more weight estimation cells defined, and enter a number in the W_{user} column.

1.5.7 Center of Gravity

This option allows the user to calculate the airplane weight and center of gravity location for a specific loading scenario by entering weight components and their corresponding center of gravity locations in a preformatted table. After selecting Center of Gravity, a menu with three options appears:

- **Copy Class I C.G.** With this option, the values for the Class I center of gravity locations from the Class I Detailed center of gravity tables are copied to the Class II center of gravity table. Using this option, the center of gravity values in the Class II table will be overwritten.

- **Component C.G.** This module calculates the center of gravity location in terms of the wing mean geometric chord, based on basic geometry and center of gravity input parameters. The module also calculates the C.G. locations of the fuselage, fuel, wing, canard, horizontal tail, vertical tail, V-tails and tailbooms.
- **Empty Weight** With this option, empty weight components and the associated center of gravity coordinates can be tabulated. The center of gravity of the empty airplane will be computed using only the components for which all data is supplied.
- **Total C.G.** This allows the user to calculate the Center of Gravity Location of the airplane for the specified loading scenario.
- **Passengers** This allows the user to specify passenger groups and calculates the C.G. of each group.
- **Forward-Aft C.G.** This module calculates the most forward and the most aft C.G. of the airplane based on minimum and maximum weights specified by the user for each component. It also plots the C.G. envelope.

1.5.8 Inertias

This option allows the user to calculate the airplane moment of inertias by entering components and their corresponding weights, moments of inertia, and center of gravity locations in a preformatted table. Also, the moments of inertia for the wing, horizontal tail, vertical tail, V-tail, canard, fuselage, tailbooms, stores, nacelles and floats are calculated based on geometric and structural parameters.

1.5.9 Set Category

If the user wishes to use **Class II** Weight estimation methods other than those chosen by the program, the **Set Category** option can be used. Selecting the **Set Category** button will display a dialog box with options to choose any of the categories described below. The following is a recommendation of categories for various types of airplanes:

- **General Aviation** — For homebuilts, single engine props, twin-engine props, agricultural, regional turboprops with a W_{TO} below 12,500 lb, low speed military trainers and small and low speed flying boats, amphibious or float airplanes.
- **Commercial** — For business jets, regional turboprops with a W_{TO} above 12,500 lb, jet transport, commercial supersonic transports and large and high speed flying boats, amphibious or float airplanes.
- **Military Transport/Cargo** — For military patrol, bomb and transport airplanes, supersonic patrol, bomb and transport airplanes and military large flying boats, amphibious or float airplanes.
- **Military Bomber** — For military patrol, bomb and transport airplanes, supersonic patrol, bomb and transport airplanes.
- **USAF Fighter (Land Based)** — For high speed military trainers, fighter airplanes and attack airplanes operating from land bases.
- **Navy Fighter (Land/Carrier Based)** — For high speed military trainers, fighter airplanes and attack airplanes operating from land and carrier bases.

2 Aerodynamics Module

2.1 General Description

The purpose of the **Aerodynamics** module is to estimate the airplane lifting surface coefficients and the total airplane drag coefficient for different flight conditions. Use of the **Aerodynamics** module options will be described in the following sections.

2.2 Aerodynamics Main Window

After selecting the **Aerodynamics** module, the user can select from the five options displayed:

- **Lift** — The **Lift** submodule can be used for estimations of the lifting characteristics of airplane lifting surfaces and high lift devices. The options provided in this module are discussed in Section 2.3.
- **Drag** — The **Drag** submodule can be used for estimations of the drag characteristics of the airplane. The options provided in this module are discussed in Section 2.4.
- **Moment** — The **Moment** submodule can be used for estimations of the moment characteristics of the airplane. The options provided in this module are discussed in Section 2.5.
- **Aerodynamic Center** — The **Aerodynamic Center** submodule can be used to calculate aerodynamic center locations of airplane lifting surfaces. The options provided in this module are discussed in Section 2.6.
- **Power Effects** — The **Power Effects** submodule can be used to calculate the effects of power on the horizontal tail dynamic pressure ratio and downwash angle and on the airplane lift and pitching moment coefficients. This option is available for tail aft airplanes. The options provided in this module are discussed in Section 2.7.
- **Ground Effects** — The **Ground Effects** submodule can be used to calculate the ground effects on airplane lift. The options provided in this module are discussed in Section 2.8.

- **Dynamic Pressure Ratio** The **Dynamic Pressure Ratio** submodule can be use to calculate the dynamic pressure at the horizontal tail in the linear lift range. The options provided in this module are discussed in Section 2.9.

2.3 Lift

The purpose of the **Lift** submodule is to:

- Determine whether or not a selected wing geometry gives the required value of clean airplane maximum lift coefficient.
- Determine the type and size of high lift devices needed to meet the maximum lift requirement for the take-off and landing conditions.

The methodology used for verifying clean airplane maximum lift coefficient and for sizing high lift devices can be found in Chapter 7 of Reference 2. The methodology used to calculate the airplane drag polars is described in References 1 and 7.

After selecting the **Lift** submodule in the **Aerodynamics** main window, eight new options will be displayed. The options are the following:

- **Wing** For calculation of the lift coefficient of the clean wing. This option is described in Section 2.3.1
- **Horizontal Tail** For calculation of the lift coefficient of a horizontal tail. This option is described in Section 2.3.1
- **Vertical Tail** For calculation of the Side Force of a vertical tail. This option is described in Section 2.3.1
- **Canard** For calculation of the lift coefficient of a canard. This option is described in Section 2.3.1
- **V-Tail** For calculation of the lift coefficient of a v-tail. This option is described in Section 2.3.1
- **Flap** For calculation of the lift coefficient of the wing with flap deflection. This option is described in Section 2.3.2
- **Nacelle/Pylon** For calculation of the lift coefficients for nacelles and pylons.

- **Airplane** For calculation of the airplane steady state lift coefficient and angle of attack.

The procedure to use each lift submodule is presented in the following sections. The methods used in calculating the lift coefficient of all airplane lifting surfaces are the same.

2.3.1 Wing / Horizontal Tail / Vertical Tail / Canard / V-Tail

The **Wing**, **Horizontal Tail**, **Vertical Tail**, **Canard**, and **V-Tail** submodules have three options:

- C_{L_α} To determine the lifting surface lift curve slope.
- ε To determine the horizontal tail/canard/v-tail downwash/upwash gradients (displayed only when the airplane is defined as having either a horizontal tail, canard, or v-tail).
- C_{L_o} & α_o To determine the lifting surface zero angle-of-attack lift coefficient and zero-lift angle of attack.
- $C_{L_{\max}}$ To determine the airfoil and lifting surface maximum lift coefficients. This option is described in Section 2.3.1.1.
- $Linear\ C_L$ To determine the lift coefficient for a given angle of attack in the linear portion of the lift curve.
- $Non-Linear\ C_L$ To determine the lift coefficient for a given angle of attack in the non-linear portion of the lift curve.
- **Lift Distribution** To determine the lifting surface spanwise lift distribution. This option is described in Section 2.3.1.2.

2.3.1.1 Maximum Lift Coefficient

The following options are presented once the $C_{L_{\max}}$ submodule is selected:

- **Airfoil** $c_{l_{\max}}$
- **Surface** $C_{L_{\max}}$

The methodology used to calculate the lifting surface root and tip airfoil maximum lift

coefficient is described in Chapter 7 of Reference 2. To calculate the surface root or tip airfoil maximum lift coefficient, select the **Airfoil** $c_{l_{\max}}$ button. An input/output window appears containing the surface root and tip airfoil type inputs. Each is a pull down list with six different symmetric or cambered airfoil types as follows:

- NACA 4 & 5 Digit Symm — For NACA four and five digit symmetrical series airfoils.
- NACA 6 Digit Symmetric — For NACA six digit series symmetrical airfoils.
- MS (1) Cambered — For NASA medium speed airfoils.
- NACA 4 & 5 Digit Camb — For NACA four and five digit series cambered airfoils.
- NACA 6 Digit Cambered — For NACA six digit series cambered airfoils.
- Other, User Defined — For a user defined airfoil.

To calculate the lifting surface planform maximum lift coefficient, select the **Surface** $C_{L_{\max}}$ button. An input/output window appears showing the surface planform lift coefficient input and output parameters. The user can supply the data of other airfoils by choosing "user defined" and defining the root and tip airfoil maximum lift coefficients in the input menu for the surface planform maximum lift coefficient.

2.3.1.2 Lift Distribution

The methodology used to determine the lifting surface spanwise lift distribution is based on lifting line theory. To determine the spanwise lift distribution, select the **Lift Distribution** button. An input/output window appears showing the surface planform input parameters. The user can display the lift distribution by selecting the **Plot** button.

2.3.1.3 Airplane Lift Coefficient and Downwash Zero-angle-of-attack

This submodule can be used to determine the lift coefficients, downwash angle, and upwash angle at zero airplane angle of attack, and the zero lift angle of attack. This module includes flap effects. Before the C_{L_o} submodule can be selected, the user must define one of three types of airplane configurations in the Airplane Configuration dialog box (See Section 2.2.3, Figure 2.16).

2.3.2 High Lift Devices

The function of the **High Lift Device** submodule is to determine the type and size of high lift devices needed to meet the maximum lift requirement for take-off and landing conditions. To determine the type and size of the high lift devices needed, select the **High Lift Device** button. The user must first select the desired flap type from Flap/Slat dialog box (See Section 2.2.3, Figure 2.19). Two options are presented in the **High Lift Device** submodule. These options are as follows:

- **Sizing** — For calculating the required high lift device size, the desired values of the trimmed lift coefficients can be determined from the **Performance** module (see Section 3) or the user may estimate them. The **Plot** option is used to display the wing geometry including the size and location of the high lift devices. The program determines whether the take-off condition or landing condition sizes the high lift device.
- **Lift** — To allow the user to verify whether the selected high lift devices can produce the desired trimmed airplane lift coefficient for a specific flight condition.

2.4 Drag

After selecting Drag, the following options are displayed:

- **Class I** — See Section 2.4.1 to use the Class I method.
- **Class II** — See Section 2.4.2 to use the Class II method.
- **Drag Distribution** — The **Drag Distribution** can be used to calculate spanwise drag on the wing, horizontal tail, vertical tail, canard, and v-tail. To determine the spanwise drag distribution, select the lifting surface button. An input/output window appears showing the surface planform input parameters. The user can display the drag distribution by selecting the **Plot** button.
- **Critical Mach** — The **Critical Mach** submodule can be used to calculate the Critical

Mach number for the airplane.

2.4.1 Estimation of Class I Drag Polars

The Class I Drag module has the following eight options.

- **T.O. Gear Down** For flaps in take-off configuration with gear down.
- **T.O. Gear Up** For flaps in take-off configuration with gear up.
- **Clean** For configuration with no flap deflection and gear up.
- **Land. Gear Up** For flaps in landing configuration with gear up.
- **Land. Gear Down** For flaps in landing configuration with gear down.
- **OEI** For one engine inoperative configuration.
- **Current Flt. Cond.** For the current airplane flight condition.
- **All Polars** Calculates all the drag polars for Class I Drag.

The methodology used to calculate the drag polar can be found in Chapter 3 of Reference 1. To calculate the drag polar, the user first selects the switch corresponding to the configuration of interest. The other five flight condition options will have similar input and output parameters.

The Class I Drag module relates the total airplane lift coefficient to the total airplane drag coefficient by the drag polar equation:

$$C_D = C_{D_{o\,clean}} + \frac{1}{\pi A R_w e} C_L{}^2$$

Where C_{D_o} and B_{DP} are coefficients calculated by the program using the methods in Section 3.4.1 of Reference 1. The program allows the user to perform this calculation in different ways. The standard method of computing C_{D_o} and B_{DP} is to specify all the input parameters and select the **Calculate** button. Equivalent parasite area is a function of the regression coefficients ‘a’ and ‘b’ (Reference 1, Section 3.4.1), and are user-defined in the input parameter section. If ‘a’ and ‘b’ are defined, the program automatically calculates the value of the equivalent parasite area. However, if the resulting equivalent parasite area or airplane wetted area is unacceptable, the user has the capability of redefining these quantities by following these steps for the equivalent parasite area:

- Input the desired value for equivalent parasite area
- Make ‘a’ or ‘b’ undefined
- Select **Calculate**

The same procedure applies to the airplane wetted area. The wetted area is a function of the regression coefficients ‘c’ and ‘d’ (Reference 1, Section 3.4.1), and are user-defined in the input parameter section. To provide a user selectable value for the wetted area, follow these steps for the wetted area:

- Input the desired value for wetted area
- Make ‘c’ or ‘d’ undefined
- Select **Calculate**

After calculating the drag polar, a dialog window displays the drag polar equation. This equation is printed with the **Print Parameters** option. After calculating the drag polar equation, the user may display the drag polar by selecting the **Plot** option. After selecting **Plot**, the following graphs will be displayed for the selected condition:

- C_L vs C_D
- C_L vs C_L / C_D
- C_L vs C_L^3 / C_D^2 (For propeller powered configurations)
- C_L vs $C_L^{0.5} / C_D$ (For jet powered configurations)

A description of the standard plot options can be found in Chapter 2 of Part II of this user's manual.

NOTE: The C_L range must be specified in input parameters. Changing the plot axis will not allow for calculation outside of the specified C_L range.

2.4.2 Estimation of the Class II Drag Polar

The purpose of the Class II Drag submodule is to supply a Class II method for predicting drag polars of airplanes during the preliminary design phase. After invoking **Class II Drag**, the program requires the definition of the altitude and speed, in the Flight Condition Dialog, to determine the

flow regime for that particular flight condition. The different flow regimes are divided, according to Mach number ranges, into:

- **Subsonic** Flow regime for flight Mach numbers not exceeding 0.6.
- **Transonic** Flow regime for flight Mach numbers between 0.6 and not exceeding 1.2.
- **Supersonic** Flow regime for flight Mach numbers between 1.2 and not exceeding 3.0.

NOTE: Drag estimation methods for the hypersonic flow regime, flight Mach numbers greater than 3.0, are not available in this module.

Once the flow regime has been selected, the user will enter the Class II Drag Polar Prediction menu, which has the following options:

2.4.2.1	**Wing**	For estimation of the wing drag coefficient.
2.4.2.2	**Horizontal Tail**	For estimation of the horizontal tail drag coefficient.
2.4.2.3	**Vertical Tail**	For estimation of the vertical tail drag coefficient.
2.4.2.4	**Canard**	For estimation of the canard drag coefficient.
2.4.2.5	**V-Tail**	For estimation of the v-tail drag coefficient.
2.4.2.6	**Ventral Fin**	For estimation of ventral fin drag coefficient.
2.4.2.7	**Fuselage**	For estimation of the fuselage drag coefficient.
2.4.2.8	**Nacelle**	For estimation of the nacelle drag coefficient.
2.4.2.9	**Tailboom**	For estimation of the tailboom drag coefficient.
2.4.2.10	**Float**	For estimation of the float drag coefficient.
2.4.2.11	**Trail. Edge Flap**	For estimation of the trailing edge flap drag coefficient.
2.4.2.12	**Lead. Edge Flap**	For estimation of the leading edge flap drag coefficient.
2.4.2.13	**Landing Gear**	For estimation of the gear drag coefficient.
2.4.2.14	**Canopy**	For estimation of the canopy drag coefficient.
2.4.2.15	**Windshield**	For estimation of the windshield drag coefficient.
2.4.2.16	**Store**	For estimation of the stores drag coefficient.
2.4.2.17	**Trim**	For estimation of the trim drag coefficient.
2.4.2.18	**Spoiler**	For estimation of the spoiler drag coefficient.
2.4.2.19	**Speed Brake**	For estimation of the speed brake drag coefficient.

2.4.2.20	**Miscellaneous**	For estimation of the miscellaneous drag coefficient.
2.4.2.21	**Pylon**	For estimation of the pylon drag coefficient.
2.4.2.22	**Windmilling**	For estimation of the drag coefficient due to windmilling.
2.4.2.23	**Inlet**	For estimation of the inlet drag coefficient.
2.4.2.24	**Nozzle**	For estimation of the exhaust nozzle drag coefficient.
2.4.2.25	**Total Drag**	For a summation of the different component drag coefficients.
2.4.2.26	**Recalculate All**	Used to recalculate all of the drag coefficients by pressing calculate once.
2.4.2.27	**Trendline**	For calculating a Trendline of the drag polar.
2.4.2.28	**Plot**	For plotting the trimmed and untrimmed drag polars.

2.4.2.1 Wing Drag

In this module, the wing drag coefficient can be calculated for a specific flight condition. The wing drag coefficient consists of a zero lift component and a lift dependent component. The methodology used to calculate the wing drag coefficient is described in Section 4.2 of Reference 7. The Wing Drag estimation method depends on the selected flow regime.

2.4.2.2 Horizontal Tail Drag

In this module, the horizontal tail drag coefficient can be calculated for a specific flight condition. The horizontal tail drag coefficient consists of a zero lift component and a lift dependent component. The methodology used to calculate the horizontal tail drag coefficient is described in Section 4.4 of Reference 7. The Horizontal Tail input/output windows depend on the selected flow regime.

2.4.2.3 Vertical Tail Drag

In this module, the vertical tail drag coefficient can be calculated for a specific flight condition. The vertical tail drag coefficient consists of a zero side force component and a side force dependent component. The methodology used to calculate the vertical tail drag coefficient is described in Section 4.4 of Reference 7. The Vertical Tail input/output windows depend on the selected flow regime.

2.4.2.4 Canard Drag

In this module, the canard drag coefficient can be calculated for a specific flight condition. The canard drag coefficient consists of a zero lift component and a lift dependent component. The methodology used to calculate the canard drag coefficient is described in Section 4.4 of Reference 7. The Canard input/output windows depend on the selected flow regime.

2.4.2.5 V-Tail Drag

In this module, the v-tail drag coefficient can be calculated for a specific flight condition. The v-tail drag coefficient consists of a zero lift component and a lift dependent component. The methodology used to calculate the v-tail drag coefficient is based on theory in Section 4.4 of Reference 7. The V-Tail input/output windows depend on the selected flow regime.

2.4.2.6 Ventral Fin Drag

In this module, the v-tail drag coefficient can be calculated for a specific flight condition.

2.4.2.7 Fuselage Drag

In this module, the fuselage drag coefficient can be calculated for a specific flight condition. The fuselage drag coefficient consists of a zero lift component and a lift dependent component. The methodology used to calculate the fuselage drag coefficient is described in Section 4.3 of Reference 7. The Fuselage input/output windows depend on the selected flow regime.

2.4.2.8 Nacelle Drag

In this module, the nacelle drag coefficient can be estimated. The methodology used to calculate the nacelle drag coefficient is described in Section 4.5 of Reference 7. For estimation of the nacelle drag coefficient, the nacelle drag consists of an isolated nacelle component and an interference component. The Nacelle drag input/output window depends on the selected flow regime and the propulsion type. Before entering the Nacelle input/output window, the user is required to input the number of nacelles. If the propeller driven option has been selected, then the supersonic flow regime cannot be used.

2.4.2.9 Tailboom

In this module, the tailboom drag coefficient can be estimated. The methodology used to calculate the tailboom drag coefficient is described in Sections 4.3 and 4.13 of Reference 7. The tailboom input/output window depends on the selected flow regime. Before entering the tailboom input/output window, the user is required to define the number of tailbooms.

2.4.2.10 Floats

In this module, the float drag coefficient can be estimated. DARcorporation developed the methodology used to calculate the float drag. The float drag estimation is only valid in the low subsonic speed regime. Before entering the float input/output window, the user is required to define the number of floats.

2.4.2.11 Trailing Edge Flap Drag

In this module, the drag coefficient of wing trailing edge lift generating devices can be estimated. The assumption is made that flap deployment will occur only in the subsonic speed regime. The flap drag estimation is therefore only valid in the subsonic speed regime. The methodology used to calculate the flap drag coefficient is described in Section 4.6 of Reference 7.

2.4.2.12 Leading Edge Flap Drag

In this module, the drag coefficient of wing leading edge lift generating devices can be estimated. The assumption is made that flap deployment will occur only in the subsonic speed regime. The flap drag estimation is therefore only valid in the subsonic speed regime. The methodology used to calculate the flap drag coefficient is described in Section 4.6 of Reference 7.

2.4.2.13 Landing Gear Drag

In this module, the drag coefficient for different landing gear types can be estimated. The landing gear drag estimation is only valid in the low subsonic speed regime. The methodology used to calculate the gear drag coefficient is described in Section 4.7 of Reference 7. Landing gear estimation methods are available for the following gear types:

- Fixed For estimation of the fixed gear drag coefficient.

- Retractable — For estimation of the retractable gear drag coefficient. The number of gears must be entered before the input/output window will appear.

2.4.2.14 Canopy Drag

In this module, the canopy drag coefficient can be calculated. The methods used in this module are only valid in the subsonic speed regime. In the transonic and supersonic speed regimes, the wave drag generated by the canopy can be significant. In these speed ranges, it will be necessary to employ area-ruling to reduce the wave drag to a minimum. The methodology used to calculate the canopy drag coefficient is described in Section 4.8 of Reference 7.

2.4.2.15 Windshield Drag

In this module, the windshield drag coefficient can be calculated. The methods used in this module are only valid in the subsonic speed regime. In the transonic and supersonic speed regimes, the wave drag generated by the windshield can be significant. In these speed ranges, it will be necessary to employ area-ruling to reduce the wave drag to a minimum. The methodology used to calculate the windshield drag coefficient is described in Section 4.8 of Reference 7.

2.4.2.16 Stores Drag

In this module, the store(s) drag coefficient can be calculated. The methodology used to calculate the stores drag coefficient is described in Section 4.9 of Reference 7. Before entering the Stores Drag input/output window, the user will be required to enter the number of stores and to define which of the stores are on the airplane for the particular flight condition. The Stores Drag input/output windows depend on the selected flow regime.

2.4.2.17 Trim Drag

In this module, the trim drag coefficient can be calculated for a specific flight condition. The methodology used to calculate the trim drag coefficient is described in Section 4.10 of Reference 7.

2.4.2.18 Spoiler Drag

In this module, the spoiler drag coefficient can be calculated. The methodology used to calculate the spoiler drag coefficient is described in Section 4.12 of Reference 7. Before entering the spoiler drag input/output window, the user will be required to define whether the spoiler is retracted or deployed for the particular flight condition.

2.4.2.19 Speed Brake

In this module, the speed brake drag coefficient can be calculated. The methodology used to calculate the speed brake drag coefficient is described in Section 4.12 of Reference 7. Before entering the speed brake drag input/output window, the user will be required to define whether the speed brake is retracted or deployed for the particular flight condition.

2.4.2.20 Miscellaneous Drag

In this module, the miscellaneous drag coefficient can be calculated. Miscellaneous drag may consist of drag due to struts, antennas or exhaust nozzle integration, to name a few possibilities. The methodology used to calculate the miscellaneous drag coefficient is described in Section 4.12 of Reference 7.

2.4.2.21 Pylon Drag

In this module, the pylon drag coefficient can be estimated. The methodology used to calculate the pylon drag coefficient is described in Section 4.5 of Reference 7. Before selecting the Pylon option, the user must specify the number of pylons. For estimation of the pylon drag coefficient, the pylon drag coefficient consists only of a zero lift component. It is assumed that the lift dependent drag component of a pylon is negligible.

2.4.2.22 Windmilling Drag

In this module, the drag coefficient due to a windmilling condition can be estimated. The methodology used to calculate the nacelle drag coefficient is described in Section 4.5 of Reference 7. Before selecting the **Windmilling** option, the user must specify the type of engine. If the propeller driven option has been selected, then the supersonic flow regime cannot be used.

2.4.2.23 Inlet

This module is used to calculate the inlet drag coefficient caused by subsonic inlet spillage.

2.4.2.24 Nozzle

This module is used to estimate the drag due to exhaust nozzles.

2.4.2.25 Total Drag

In this module, the total drag coefficient can be calculated. The calculation consists of the summation of all previous estimated component drag coefficients.

2.4.2.26 Recalculate All

This module allows the user to recalculate all of the drag coefficients by pressing calculate once. The user can change a parameter in the input and view its effect on the drag coefficients. A drag coefficient will only be recalculated if all of its associated input is complete.

2.4.2.27 Trendline

In this module, a fifth order curve is fit to the Class II Drag Polar.

2.4.2.28 Plot

In the Class II Drag module, different drag polars can be generated. After invoking **Plot**, the following five options will be displayed:

- C_L - C_D M=Const. For generating drag polars for constant Mach number. After selection of this option the drag component selection list will be displayed. Each drag component selected in this menu will be used for generating the Class II drag polars.
- C_L - C_D δ_f =Const. For generating drag polars for constant flap deflection angles. This option can only be used in the subsonic flow regime. After selection of this option, the drag component selection list will be displayed. Each drag component selected in this menu will be used for generating the Class II drag polars.

- C_D - M C_L =Const. — For generating C_D - M curves for constant lift coefficient. After selection of this option, the drag component selection list will be displayed. Each drag component selected in this menu will be used for generating the C_D - M curves.
- **Drag Build-Up** — For generating drag polars built up of different drag components. After selection of this option, the drag component build-up list will be displayed. The selected order of the drag components in the drag build up menu will determine how the Class II drag polar will be built up.
- $C_D - \alpha$ — For generating $C_D - \alpha$ curves. Each drag component selected in this menu will be used for generating the $C_D - \alpha$ curves.

A component can be selected by clicking on the component name or the selection box to the left of the component. After the component selection, the user can select either trimmed or untrimmed drag polar option. The lift coefficient that is plotted is dependent on which component or combination of components is selected. All selected combinations result in a Class II drag polar plot in terms of the airplane steady state lift coefficient, with a few exceptions (see Table 2.1). For the first three options listed above, a check mark will appear in the selection box. For the **Drag Build-Up** option a number is displayed in the selection box indicating the order of plotting. The user can deselect an option by clicking on it again.

Table 2.1 Plot Lift Coefficients Based on Component Selected

Component Selected	Plot Lift Coefficient
Wing only	Clean Wing Lift Coefficient
Horizontal Tail only	Horizontal Tail Lift Coefficient
Canard only	Canard Lift Coefficient
Flap only	Clean Wing Lift Coefficient
Wing and Flap only	Clean Wing Lift Coefficient

2.4.3 Estimation of the Wind Tunnel Drag

This module is used for the correction of wind tunnel drag on the various components. The full-scale zero-lift drag coefficients are scaled using appropriate Reynold's number and Mach number corrections. Drag polars at various control surface deflections are entered and scaled up to full-scale and can be used in Class II trim analysis.

2.5 Moment

After selecting the **Moment** submodule in the **Aerodynamics** main window, five new options will be displayed. The options are the following:

- **Wing** — For calculation of spanwise moment distribution on the wing. The user can display it by selecting the **Plot** button.
- **Horizontal Tail** — For calculation of spanwise moment distribution on the horizontal tail. The user can display it by selecting the **Plot** button.
- **Vertical Tail** — For calculation of spanwise moment distribution on the vertical tail. The user can display it by selecting the **Plot** button.
- **Canard** — For calculation of spanwise moment distribution on the canard. The user can display it by selecting the **Plot** button.
- **V-Tail** — For calculation of spanwise moment distribution on the v-tail. The user can display it by selecting the **Plot** button.
- **Airplane** — For calculation of Airplane pitching moment coefficient as well as moment derivatives for the airplane.

2.5.1 Pitching Moment Coefficient at Zero-angle-of-attack

This submodule can be used to determine the zero lift airplane pitching moment coefficients, and pitching moment coefficients at zero airplane angle of attack. This module includes flap effects. To account for each airplane component, the pitching moment coefficient components are calculated separately. The user is presented with the following options:

2.5.1	**Zero Lift**	For estimation of the zero lift pitching moment coefficient.
2.5.2	**Trailing Edge**	For estimation of the effect of trailing edge flaps on lift and pitching moment coefficients.
2.5.3	**Leading Edge**	For estimation of the effect of leading edge flaps on lift and pitching moment coefficients.
2.5.4	**Total**	For calculation of the total pitching moment coefficient at zero angle of attack.

2.5.2 Zero Lift Pitching Moment Coefficient

This submodule can be used to determine the zero lift airplane pitching moment coefficient. The coefficient is separated into a wing and fuselage component, and the combined wing and fuselage effect is calculated.

2.5.3 Trailing Edge Flaps

This submodule can be used to determine the change in pitching moment and wing lift coefficient at zero angle of attack due to a trailing edge flap deflection. Before the **Trailing Edge** submodule can be selected, the user must define the desired trailing edge flap type from the Airplane Configuration dialog box.

2.5.4 Leading Edge Flaps

This submodule can be used to determine the change in pitching moment due to a leading edge flap deflection. Before the **Leading Edge** submodule can be selected, the user must define the desired leading edge flap type from the Airplane Configuration dialog box (See Section 2.2.3, Figure 2.16).

2.5.5 Total Pitching Moment Coefficient at Zero Angle of Attack

This submodule can be used to determine the airplane pitching moment coefficient at zero angle of attack. Before the **Total** submodule can be selected, the user must define one of five types of airplane configurations in the Airplane Configuration dialog box (See Section 2.2.3, Figure 2.16). The leading and trailing edge flap type and contributions must also be defined as presented in Sections 2.5.2 and 2.5.3.

The total airplane pitching moment coefficient at zero angle of attack is calculated in components. The effect of wing, fuselage, horizontal tail, v-tail and canard are included in the total pitching moment coefficient.

2.6 Aerodynamic Center

The purpose of the **Aerodynamic Center** submodule is to determine the Aerodynamic Center of the airplane. The methodology used for finding the Aerodynamic Center can be found in Chapter 8 of Reference 7.

Once the **Aero. Center** button is selected, a new menu appears allowing the user to calculate the aerodynamic center shift due to the fuselage, nacelles, stores tailbooms, floats, wing, horizontal tail, vertical tail, canard, v-tail, and aerodynamic center for the airplane. The methodology used to calculate the aerodynamic center shift due to the fuselage, nacelles, stores and tailbooms can be found in Section 8.2.5.3 of Reference 7. Procedures outlining the use of each aerodynamic center shift submodules are presented in the following subsections:

2.6.1	**Fuselage**	For calculating the aerodynamic shift due to the fuselage.
2.6.2	**Nacelle**	For calculating the aerodynamic shift due to nacelles.
2.6.3	**Store**	For calculating the aerodynamic shift due to stores.
2.6.4	**Tailboom**	For calculating the aerodynamic shift due to tailbooms.
2.6.5	**Float**	For calculating the aerodynamic shift due to floats.
2.6.6	**Pylon**	For calculating the aerodynamic shift due to pylons.
2.6.7	**Power**	For calculating the aerodynamic shift due to power.
2.6.8	**Wing**	For calculating the aerodynamic shift due to the wing.

2.6.9	**Horizontal Tail**	For calculating the aerodynamic shift due to the horizontal tail.
2.6.10	**Vertical Tail**	For calculating the aerodynamic shift due to the vertical tail.
2.6.11	**Canard**	For calculating the aerodynamic shift due to the canard.
2.6.12	**V-Tail**	For calculating the aerodynamic shift due to the v-tail.
2.6.13	**Ventral Fin**	For calculating the aerodynamic shift due to the ventral fin.
2.6.14	**Airplane**	For calculating the aerodynamic of the airplane.

2.6.1 Aerodynamic Center Shift due to the Fuselage

When the user selects the **Fuselage** button, an input/output window appears allowing the user to calculate the aerodynamic center shift based on the fuselage geometry defined in Section 4.3.

NOTE: The calculated value of the aerodynamic center shift due to the fuselage in terms of the wing mean geometric chord will be transferred into the C_{m_u} and C_{m_α} submodule input groups.

2.6.2 Aerodynamic Center Shift due to the Nacelles

When the user selects the **Nacelles** button, the number of nacelles must be specified in the Airplane Configuration dialog box. A maximum of ten nacelles may be defined. After the number of nacelles is defined, an input/output window appears. In this window X_{nose_n} is the X-coordinate of each nacelle inlet, Y_{nose_n} is the Y-coordinate of each nacelle centerline, and $N_{n_{segments}}$ is the number of segments into which each nacelle is to be divided. The maximum number of segments that can be entered for each nacelle is 50. The first input group consists of a number of general aerodynamic center shift parameters. The second group consists of a table listing the number of nacelle segments in the nacelle along with input parameters for each segment.

The **Next Nacelle** button allows the user to switch to the next nacelle table. When the user wishes to input data for each of the defined nacelles, the **Next Nacelle** button should be used. This

procedure is followed until the last nacelle appears on the screen. If the last nacelle is displayed, selecting the **Next Nacelle** button will display the first nacelle table. The X- and Y-coordinates of each nacelle must be entered in the input group for every nacelle. The user may add or delete a nacelle by changing the number of nacelles in the Airplane Configuration dialog box. After the input parameters and all of the input table(s) have been defined, the user selects the **Calculate** button to observe the computed output parameters. The value of the aerodynamic center shift due to nacelles in terms of the wing mean geometric chord will be transferred into the C_{m_u} and C_{m_α} submodule input menus.

2.6.3 Aerodynamic Center Shift due to Stores

When the user selects the **Stores** button, the menu selections and procedures are identical in every respect to the aerodynamic center shift due to nacelles.

2.6.4 Aerodynamic Center Shift due to Tailbooms

When the user selects the **Tailbooms** button, the menu selections and procedures are identical in every respect to the aerodynamic center shift due to nacelles.

2.6.5 Aerodynamic Center Shift due to Floats

When the user selects the **Floats** button, the menu selections and procedures are identical in every respect to the aerodynamic center shift due to nacelles.

2.6.6 Aerodynamic Center Shift due to Pylons

This submodule calculates the location of the pylon Aerodynamic Center, based on the pylon geometry and the location on the airplane.

2.6.7 Aerodynamic Center Shift due to Power Effects

This submodule calculates the shift in aerodynamic center due to power effects.

2.6.8 Wing Aerodynamic Center

This submodule calculates the location of the wing Aerodynamic Center.

2.6.9 Horizontal Tail Aerodynamic Center

This submodule calculates the location of the horizontal tail Aerodynamic Center.

2.6.10 Vertical Tail Aerodynamic Center

This submodule calculates the location of the vertical tail Aerodynamic Center.

2.6.11 Canard Aerodynamic Center

This submodule calculates the location of the canard Aerodynamic Center.

2.6.12 V-Tail Aerodynamic Center

This submodule calculates the location of the v-tail Aerodynamic Center.

2.6.13 Ventral Fin Aerodynamic Center

This submodule calculates the location of the ventral fin Aerodynamic Center.

2.6.14 Aerodynamic Center of the Airplane

This submodule calculates the total airplane Aerodynamic Center based on lifting surface Aerodynamic Center locations and shift contributions of other components such as fuselage, nacelles, etc..

2.7 Power Effects

The purpose of the Power Effects submodule is to determine the effects an operating engine has on the aircraft. The power effects submodule is only available when the "Include Power Effects" field is selected in the Flight Condition Dialog Box. The methodology used for determining Power Effects can be found in Chapter 8 of Reference 7 and also Reference 17.

2.8 Ground Effects

This module calculates the effect of the ground on airplane lift and pitching moment as well as calculating the effect of variation of the airplane's height above the ground. This module is

available only when the “Include Ground Effects” field is selected in the Flight Condition Dialog Box.

2.9 Dynamic Pressure Ratio

This module calculates the effects of free stream velocity on the horizontal tail, vertical tail or v-tail as it varies with angle of attack. The contribution of power effects is also included in the analysis.

3 Performance Module

3.1 General Description

The purpose of the Performance Sizing submodule is to allow for a rapid estimation of those airplane design parameters having a major impact on airplane performance. Airplanes are usually required to meet performance objectives in different categories depending on the mission profile. Meeting these performance objectives normally results in the determination of a range of values for:

- Wing loading (W/S)
- Thrust loading (T/W) or power loading (W/P)
- Airplane maximum lift coefficients ($C_{L_{\max}}$, $C_{L_{\max_{TO}}}$, and $C_{L_{\max_{L}}}$).

The variables listed above are plotted in the form of a performance-matching plot. These plots depend on the type of airplane, the applicable specification and the applicable regulation(s). With the help of such a plot, the combination of the highest possible wing loading and the smallest possible thrust (or highest power) loading, which meets all performance requirements, can be determined. The methodology used for performance sizing can be found in Reference 1.

The purpose of the Analysis submodule is to provide the user with Class II analysis methods for predicting the performance characteristics of an airplane. The methodology used to analyze the performance characteristics can be found in Chapter 5 of Reference 8.

Use of the performance module options will be described in the following sections.

3.2 Performance Main Window

After invoking the Performance module, two options are displayed:

- Sizing — The options provided in this module are discussed in Section 3.3.
- Analysis — The options provided in this module are discussed in Section 3.4.
- Export to APP — The options provided in this module are discussed in Section 3.5.

3.3 Performance Sizing

After choosing the Sizing submodule, another menu appears with seven options. The seven options represent submodules as follows:

3.3.1	**Stall Speed**	For sizing to stall speed requirements.
3.3.2	**Take-off Distance**	For sizing to take-off distance requirements.
3.3.3	**Climb**	For sizing to climb requirements.
3.3.4	**Max Cruise Speed**	For sizing to maximum cruise speed requirements.
3.3.5	**Maneuver/Turn**	For sizing to maneuvering requirements.
3.3.6	**Landing Distance**	For sizing to landing distance requirements.
3.3.7	**Matching Plot**	For plotting the performance sizing equations.

The user may choose to size an airplane by using any combination (or all) of the above sizing options. Several of the performance sizing options require input only from the user, while others also provide the user with output. Once all of the inputs for the desired options have been entered and, where applicable, the output has been calculated, the user may select the **Matching Plot** option to plot the performance sizing equations. The procedures to use each performance sizing and matching plot submodule are presented in the following sections.

3.3.1 Stall Speed Sizing

To size the aircraft to meet stall speed requirements, the user selects the Stall Speed option. The methodology used in sizing to stall speed requirements can be found in Reference 1, Section 3.1. The input and output data for the **Stall Speed** submodule are for all airplane types and specifications.

3.3.2 Take-off Distance Sizing

To size the aircraft to take-off distance requirements, the user selects the **Take-off Distance** option. The methodology used in sizing to take-off distance requirements can be found in Reference 1, Section 3.2.

3.3.3 Climb Sizing

To size the aircraft to meet climb requirements, the user selects the **Climb** option. Note that the input elements, which pertain to the specification to be satisfied, contain default values. These values can still be modified by the user as needed by selecting the **Set Default** option. The drag polar parameters can be estimated in the **Class I Drag** submodule (See Chapter 2). The methodology used in sizing to climb requirements can be found in Section 3.4 of Reference 1.

3.3.4 Maximum Cruise Speed Sizing

To size the aircraft to maximum cruise speed requirements, the user selects the **Max Cruise Speed** option. The methodology used in sizing to maximum cruise speed requirements can be found in Section 3.6 of Reference 1.

3.3.5 Maneuvering Sizing

To size the aircraft to meet maneuvering requirements, the user selects the **Maneuvering** option. This submodule sizes the airplane for both pull-up (or push-over) load factor and a specific turn rate in the level turn maneuver. The methodology used in sizing to maneuvering requirements can be found in Reference 1, Section 3.5.

3.3.6 Landing Distance Sizing

To size the aircraft to meet landing distance requirements, the user selects the **Landing Distance** option. The methodology used in sizing to landing requirements can be found in Reference 1, Section 3.3.

3.3.7 Matching Plot

After entering the data in the desired performance sizing options, the requirements can be shown in a performance-matching plot by selecting the **Matching Plot** option. When the **Matching Plot** option is selected, the system provides a list for the user to specify which performance-sizing options are to be plotted. The options can be plotted individually or in a group by selecting the desired combination of options. A check mark indicates if an option has been selected. Once the selection has been made, the user selects the **Continue** button and an input/output window appears with matching graph input parameters. The user now specifies the desired range of take-off wing loading values by defining the minimum and maximum $(W/S)_{TO}$ limits. When the user selects **Plot**, the pre-selected performance sizing options will be graphed. With the help of such a plot, the user may determine the highest possible wing loading and the smallest possible thrust (or highest power) loading which meet the performance requirements. The standard plot options are described in Chapter 2 of Part II of this manual.

3.4 Performance Analysis

After choosing the **Analysis** submodule, another menu appears with ten options. The ten options represent submodules as follows:

3.4.1	**Thrust-Speed, or**	3.4.6	**Cruise**
3.4.2	**Power-Speed**	3.4.7	**Dive & Descent**
3.4.3	**Stall Speed**	3.4.8	**Maneuver**
3.4.4	**Take-off Distance**	3.4.9	**Glide**
3.4.5	**Climb**	3.4.10	**Landing Distance**

The use of these Class II mission performance analysis submodules will be described in the following sections. Many of these submodules require the use of Class I drag polar data. There are also numerous plotting options incorporated into these submodules. See Part III, Chapter 2, of the user's manual for a description of the **Drag Polar** module. A detailed explanation of the plot options can be found in Part II, Chapter 2, of the user's manual.

3.4.1 Thrust-Speed Performance Curve

To define a **Thrust-Speed** curve, the user needs to know three points on the thrust versus speed curve. The user should specify the three known points in the input section of the menu, in addition to the minimum and maximum limits of speed applicable to the curve.

3.4.2 Power-Speed Performance Curve

To define a **Power-Speed** curve, the user needs to know three points on the power versus speed curve. The user should specify the three known points in the input section of the menu, in addition to the minimum and maximum limits of speed applicable to the curve.

3.4.3 Stall Speeds

To run the **Stall Speed** submodule, the thrust (or power) versus speed performance curve must first be defined. Once the **Stall Speed** option has been selected, another menu appears showing the stall speed options:

- **Take-off** For the stall speed in the take-off configuration.
- **Clean** For the stall speed in a clean configuration.
- **Landing** For the stall speed in the landing configuration.
- **Current Flt. Cond.** For the current flight condition stall speed.

The **Stall Speed** module option works two ways:

1. The user inputs the thrust (power) at which the stall speed is to be determined.
2. The user leaves the thrust (power) undefined, and the performance curves are used to determine the stall speed. The performance curves should then be defined for the throttle setting in the stall maneuver.

The methodology used in the stall speed analysis can be found in Section 5.1 of Reference 8.

3.4.4 Take-off Distance

To run the **Take-off Distance** submodule, the thrust (or power) versus speed performance curve must first be defined. The take-off gear down drag polar must also be known (See Chapter 2, Part III of the user's manual). Once the **Take-off Distance** option has been selected, another

window appears showing the Class II take-off field length input and output parameters. There are two default settings in the take-off distance option. These default settings, described below, are used if the listed variable is left undefined in the input.

1. $(L/D)_{OEI}$ The lift to drag ratio at take-off with one engine inoperative will be found using the maximum lift coefficient at take-off and the take-off gear down drag polar.
2. T_{set} The thrust setting will be determined using the defined performance curves at the lift-off velocity. See Part III, Section 3.4.1 in the user's manual for a description of the performance curves.

The methodology used in the take-off distance analysis can be found in Section 5.2 of Reference 8.

3.4.5 Climb

To run the **Climb** submodule, the thrust (or power) versus speed performance curves must first be defined. The clean configuration drag polar must also be known (See Chapter 2, Part III of the user's manual). Once the **Climb** option has been selected, another menu appears showing the climb options:

- **Climb Perform.** Contains rate of climb, climb gradient, and specific excess power.
- **Time to Climb** Represents the time to climb from one altitude to another.

When either the **Climb Perform.** or **Time to Climb** options have been selected, the Class II Climb input/output window is displayed. The methodology used in the climb analysis can be found in Section 5.3 of Reference 8.

3.4.6 Cruise

To run the Cruise submodule, the thrust (or power) versus speed performance curves must first be defined. The clean configuration drag polar must also be known (See Chapter 2, Part III). Once the **Cruise** option has been selected, another menu appears showing the cruise and range options:

3.4.6.1 **Maximum Speed**

3.4.6.2 **Range**

3.4.6.3 **Endurance**

3.4.6.4 **Payload-Range**

3.4.6.1 Maximum Cruise Speed

When the **Max Cruise Speed** option has been selected, a new window appears showing the Class II maximum cruise speed input and output parameters. The program iterates over thrust/power and speed to solve the cruise equations of motion until the required thrust/power is equal to the available thrust/power. The maximum cruise speed is determined by locating the intersection of the thrust/power required versus speed and thrust/power available versus speed curves. If a solution is not obtained, the plotting option enables the user to quickly see the relative positions of the two curves.

3.4.6.2 Range

The methodology used in the range analysis can be found in Section 5.4 of Reference 8. Once the Range submodule has been selected, another menu appears showing the range options:

- **Constant Speed** — For the range at constant speed. When the **Constant Speed** option has been selected, a new window appears showing the Class II Range (constant speed) input and output parameters. The angle of attack is iterated to solve the cruise equations of motion until the velocity matches user supplied input value.
- **Constant Alt.** — For the range at a constant altitude. When the **Constant Alt.** option has been selected, a new window appears showing the Class II Range (constant altitude) input and output parameters. If the lift

coefficient in the input menu is left undefined, the lift coefficient for maximum range at constant altitude, shown in the output, will be used to determine the range.

3.4.6.3 Endurance

To run the **Endurance** submodule, the thrust (or power) versus speed performance curves must first be defined. The clean configuration drag polar must also be known. Once the **Endurance** option has been selected, another menu appears showing the endurance and loiter options:

- **Constant Speed** — For the endurance at a constant speed. In this option, the angle of attack is iterated to solve the equations of motion until the velocity matches the user supplied input data.
- **Constant Alt.** — For the endurance at constant altitude. If the lift coefficient in the **Constant Alt.** input group is left undefined, the lift coefficient for maximum endurance at constant altitude, shown in the output group, will be used to determine the endurance.

The methodology used in the endurance analysis can be found in Section 5.5 of Reference 8.

3.4.6.4 Payload-Range Diagram

Once the Payload-Range submodule has been selected, another menu appears showing the payload-range diagram options:

- **Constant Speed** — For the payload-range diagram for range at constant speed.
- **Constant Alt.** — For the payload-range diagram for range at constant altitude.

The methodology used in the payload-range diagram analysis can be found in Section 5.4 of Reference 8.

3.4.7 Dive & Descent

To run the Dive & Descent submodule, the thrust (or power) versus speed performance curves must first be defined. The clean configuration drag polar must also be known. The purpose of

this submodule it to determine the flight path angle for a given dive speed. When the **Dive & Descent** option is selected, another window appears showing the Class II dive and descent input and output parameters for a given speed. The angle of attack is iterated to solve the dive and descent equations of motion until the velocity matches the user supplied input data. The methodology used in the dive and descent analysis can be found in Section 5.6 of Reference 8. When all the input parameters have been defined and the **Plot** option has been selected, the desired curves will be displayed. The two lines represent the two equations of motion for the dive condition. The purpose of this is to determine the speed for a given flight path angle in dive. The velocities at the intersections of the two curves represent solutions for the desired flight path angle.

3.4.8 Maneuver

To run the Maneuver submodule, the thrust (or power) versus speed performance curves must first be defined. The clean configuration drag polar must also be known. Once the **Maneuver** option has been selected, another menu appears showing the maneuver options:

- **Pull-Up/Push-Over** For a pull-up or push-over maneuver.
- **Level Turn** For a level turn maneuver.

Once the **Pull-Up/Push-Over** or **Level Turn** option has been selected, another list appears showing the maneuver types:

- **Instantaneous** For an instantaneous maneuver.
- **Sustained** For a sustained maneuver.

When the maneuver option and the maneuver type have been selected, another window appears showing the Class II Maneuver input and output parameters. The methodology used in the maneuver analysis can be found in Section 5.7 of Reference 8.

When the **Plot** option is selected, a plot of the maximum load factor versus speed is generated using the input from either the instantaneous pull-up/push-over or the instantaneous level turn option (the input windows for both cases contain the same information).

3.4.9 Glide

To run the Glide submodule, the thrust (power) versus speed performance curves must first be defined. The clean configuration drag polar must also be known. Once the **Glide** option has been selected, another menu appears showing the Class II Glide options:

- **Rate of Descent** — When the **Rate of Descent** option is selected, another window appears showing input and output parameters. The methodology used in the glide analysis can be found in Reference 8.
- **Time of Glide** — When the **Time of Glide** option is selected, another window appears showing input and output parameters. The methodology used in the glide analysis can be found in Reference 8.
- **Range of Glide** — When the **Range of Glide** option is selected, another window appears showing input and output parameters. The methodology used in the glide analysis can be found in Reference 8.

When the **Plot** option is selected, the selected parameter is plotted with respect to angle of attack. The rate of descent, time in the air, and glide range versus angle of attack plots are generated using the input from each respective input/output window. A detailed explanation of the plot options can be found in Part II, Chapter 2 of the user's manual.

3.4.10 Landing Distance

To run this submodule, the landing configuration drag polar must first be known. Once the **Landing Distance** option has been selected, another window appears showing the Class II Landing Distance input and output parameters. If the approach speed is known rather than the landing stall speed, the stall speed is left undefined and the approach velocity is entered in the output. The methodology used in landing distance analysis can be found in Section 5.9 of Reference 8.

3.5 Export to APP

This module exports aerodynamic and other pertinent data into Aircraft Performance Program (APP) native files. These files can be used in APP.

4 Geometry Module

4.1 General Description

The purpose of the **Geometry** module is to help the user define the geometry of the fuselage, wing, horizontal tail, vertical tail, canard and v-tail and calculate related parameters. The methodology used to calculate the airplane components geometry is described in Reference 2. Use of the **Geometry** module options will be described in the following sections.

4.2 Airplane Geometry Categories

Twelve options represent the following submodules:

- **Wing** — For calculation of the wing geometry. The options provided in this module are discussed in Section 4.3.
- **Horizontal Tail** — For calculation of the horizontal tail geometry. The options provided in this module are discussed in Section 4.4.
- **Vertical Tail** — For calculation of the vertical tail geometry. The options provided in this module are discussed in Section 4.5.
- **Canard** — For calculation of the canard geometry. The options provided in this module are discussed in Section 4.6.
- **V-Tail** — For calculation of the v-tail geometry. The options provided in this module are discussed in Section 4.7.
- **Ventral Fin** — For calculation of the ventral fin geometry. The options provided in this module are discussed in Section 4.8.
- **Fuselage** — For calculation of the fuselage geometry. The options provided in this module are discussed in Section 4.9.
- **Nacelle** — For calculation of the nacelle geometry. The options provided in this module are discussed in Section 4.10.
- **Tailboom** — For calculation of the tailboom geometry. The options provided in this module are discussed in Section 4.11.

- **Float** — For calculation of the float geometry. The options provided in this module are discussed in Section 4.12.
- **Landing Gear** — For calculation of the landing gear geometry. The options provided in this module are discussed in Section 4.13.
- **Canopy** — For calculation of the canopy geometry. The options provided in this module are discussed in Section 4.14.
- **Store** — For calculation of the store geometry. The options provided in this module are discussed in Section 4.15.
- **Pylon** — For calculation of the pylon geometry. The options provided in this module are discussed in Section 4.16.
- **Propeller** — For calculation of the propeller geometry. The options provided in this module are discussed in Section 4.17.
- **Airplane 3-View** — This option can be used to output airplane three view. The options provided in this module are discussed in Section 4.18.
- **Angles** — This option lists all the pertinent angles. The options provided in this module are discussed in Section 4.19.
- **Scale** — This option can be used to scale an entire airplane uniformly. Additionally, the airplane can be translated in the X and Z direction. The options provided in this module are discussed in Section 4.20.
- **Translate** — This option can be used to translate an entire airplane in the X and Z direction. The options provided in this module are discussed in Section 4.21.
- **Airfoil Folder** — This option can be used to specify the airfoil file location. The options provided in this module are discussed in Section 4.22.
- **AeroPack** — This option can be used to output airplane geometry that can be shared with Shark-AP or SharkFX-AP. The options provided in this module are discussed in Section 4.23.

4.3 Wing Geometry

The methodology used to calculate the wing geometry related parameters is described in Chapter 6 of Reference 2. The **Wing Geometry** submodule has eleven options:

4.3.1	**Straight Tapered**	For calculation of straight tapered wing geometry.
4.3.2	**Cranked Wing**	For calculation of the equivalent straight tapered wing geometry from a given cranked wing geometry based on the tip chord or Mean Geometric Chord.
4.3.3	**Fuel Volume**	For calculation of the volume of fuel the wing can hold based on its geometry.
4.3.4	**High Lift Device**	For calculation of the high lift device geometry (trailing edge flaps, slats, Krueger flaps, etc.) geometry.
4.3.5	**Aileron/Tab**	For calculation of aileron geometry.
4.3.6	**Spoiler**	For calculation of the spoiler parameters.
4.3.7	**Chord Length**	For calculation of wing chord based on span wise location.
4.3.8	**Airfoil**	For calculation of wing airfoil parameters.
4.3.9	**Exposed**	For calculation of exposed wing geometry.

4.3.1 Straight Tapered

The Straight Tapered wing geometry submodule has four different sets of input and output variables. Any one of these data sets can be accessed by using the appropriate menu button. After calculating the output parameters, the user may display the wing by selecting the **Plot** option.

4.3.2 Cranked Wing

This submodule can be used to calculate the equivalent straight tapered wing geometry for a cranked wing. The equivalent wing is defined as a straight tapered wing with the same net wing area as the cranked wing and with the same tip chord length or same mean geometric chord. The user can define a cranked wing by entering input data for all the panels comprising the wing. Once all input is defined, the user can calculate the equivalent straight tapered wing parameters by selection of the **Calculate** button. A plot of the cranked wing can be obtained after selection of

the **Plot** option.

4.3.3 Fuel Volume: Class I, Class II and Cranked Wing

In the **Class I** submodule, the volume of fuel that the wing can hold is calculated. It is assumed that the volume between the front and rear spars is used as the useful fuel volume. By multiplying by the density of the fuel, the fuel weight can also be found. The program will compare this weight to the maximum fuel weight in the fuel tank at any point in the mission to determine if this amount of fuel can be stored in the wing.

The **Class II** submodule calculates the allowable fuel in the wing by taking into account the following:

- Rear Spar Location
- Rear Spar Location
- Inboard and Outboard Tank Stations
- Factor to account for structure
- Factor to account for fuel expansion

The Cranked Wing submodule calculates the allowable fuel in the different panels of the wing. It takes into accout the following:

- Rear Spar Location
- Rear Spar Location
- Inboard and Outboard Tank Stations
- Factor to account for structure
- Factor to account for fuel expansion
- Thickness ratios of the panels at their root and tip

4.3.4 High Lift Device

In this submodule, the geometry of the high lift devices is specified.

4.3.5 Aileron/Tab

In this submodule, the geometry of the aileron is added.

4.3.6 Spoiler

In this submodule, the geometry of the spoiler is added.

4.3.7 Chord Length

In this submodule, the chord length of the wing at any span wise location can be determined by using root chord length, taper ratio and the given span wise location.

4.3.8 Airfoil

In this submodule, the the airfoil parameters at the wing mean geometric chord is calculated.

4.3.9 Exposed

In this submodule, the exposed wing geometry is calculated.

4.4 Horizontal Tail Geometry

When the Horizontal Tail module is selected, the user is presented with the following options:

4.4.1	**Straight Tapered**	For calculation of straight tapered horizontal tail geometry.
4.4.2	**Cranked**	For calculation of the equivalent straight tapered horizontal tail geometry from given cranked horizontal tail geometry.
4.4.3	**Volume Coefficient**	For calculation of the horizontal tail Volume Coefficient.
4.4.4	**Elevator/Tab**	For calculation of the elevator geometry.
4.4.5	**Chord Length**	For calculation of horizontal tail chord based on span wise location.
4.4.6	**Airfoil**	For calculation of airfoil parameters at the horizontal tail mean geometric chord.
4.4.7	**Exposed**	For calculation of exposed horizontal tail parameters.

4.4.1 Straight Tapered

The method for determining the geometry of a straight tapered horizontal tail is identical to the method found in Section 4.4.1 of this manual.

4.4.2 Cranked Horizontal Tail

The method for determining the geometry of a cranked horizontal tail is identical to the method found in Section 4.4.2 of this manual.

4.4.3 Volume Coefficient

This horizontal tail submodule calculates the volume coefficient of a horizontal tail planform. The methodology used to calculate the horizontal tail volume coefficient and related parameters is described in Chapter 8 of Reference 2. After calculating the output parameters, the user may display the horizontal tail geometry by selecting the **Plot** option.

4.4.4 Elevator/Tab

In this submodule, the geometry of the elevator is added.

4.4.5 Chord Length

In this submodule, the chord length of the horizontal tail at any span wise location can be determined by using root chord length, taper ratio and the given span wise location.

4.4.6 Airfoil

In this submodule, the horizontal tail airfoil parameters at the horizontal tail mean geometric chord are calculated.

4.4.7 Exposed

In this submodule, the exposed horizontal tail parameters are calculated.

4.5 Vertical Tail Geometry

When the Vertical Tail module is selected, the user is presented with the following options:

4.5.1	**Straight Tapered**	For calculation of straight tapered vertical tail geometry.
4.5.2	**Cranked**	For calculation of the equivalent straight tapered vertical tail geometry from given cranked vertical tail geometry.
4.5.3	**Volume Coefficient**	For calculation of the vertical tail Volume Coefficient.
4.5.4	**Rudder/Tab**	For calculation of the rudder geometry.
4.5.5	**Chord Length**	For calculation of vertical tail chord based on span wise location.
4.5.6	**Airfoil**	For calculation of airfoil parameters at the vertical tail mean geometric chord.
4.5.7	**Exposed**	For calculation of exposed vertical tail parameters.

4.5.1 Straight Tapered

The method for determining the geometry of a straight tapered vertical tail is identical to the method found in Section 4.5.1 of this manual.

4.5.2 Cranked Vertical Tail

The method for determining the geometry of a cranked vertical tail is identical to the method found in Section 4.5.2 of this manual.

4.5.3 Volume Coefficient

This vertical tail submodule calculates the volume coefficient of a vertical tail planform. The methodology used to calculate the horizontal tail volume coefficient and related parameters is described in Chapter 8 of Reference 2. After calculating the output parameters, the user may display the vertical tail geometry by selecting the **Plot** option.

4.5.4 Rudder/Tab

In this submodule, the geometry of the rudder is added.

4.5.5 Chord Length

In this submodule, the chord length of the vertical tail at any span wise location can be

determined by using root chord length, taper ratio and the given span wise location.

4.5.6 Airfoil

In this submodule, the vertical tail airfoil parameters at the vertical tail mean geometric chord are calculated.

4.5.7 Exposed

In this submodule, the exposed vertical tail parameters are calculated.

4.6 Canard Geometry

When the Canard module is selected, the user is presented with the following options:

4.6.1	**Straight Tapered**	For calculation of straight tapered canard geometry.
4.6.2	**Cranked Canard**	For calculation of the equivalent straight tapered canard geometry from given cranked canard tail geometry.
4.6.3	**Volume Coefficient**	For calculation of the canard Volume Coefficient.
4.6.4	**Canardvator/Tab**	For calculation of the canardvator geometry.
4.6.5	**Chord Length**	For calculation of canard chord based on span wise location.
4.6.6	**Airfoil**	For calculation of airfoil parameters at the canard mean geometric chord.
4.6.7	**Exposed**	For calculation of exposed canard parameters.

4.6.1 Straight Tapered

The method for determining the geometry of a straight tapered canard is identical to the method found in Section 4.4.1 of this manual.

4.6.2 Cranked Canard

The method for determining the geometry of a cranked canard is identical to the method found in Section 4.4.2 of this manual.

4.6.3 Volume Coefficient

This canard submodule calculates the volume coefficient of a canard planform. The methodology used to calculate the canard volume coefficient and related parameters is described in Chapter 8 of Reference 2. After calculating the output parameters, the user may display the canard geometry by selecting the **Plot** option.

4.6.4 Canardvator/Tab

In this submodule, the geometry of the canardvator is added.

4.6.5 Chord Length

In this submodule, the chord length of the canard at any span wise location can be determined by using root chord length, taper ratio and the given span wise location.

4.6.6 Airfoil

In this submodule, the canard airfoil parameters at the canard mean geometric chord are calculated.

4.6.7 Exposed

In this submodule, the exposed canard parameters are calculated.

4.7 V-Tail Geometry

When the V-Tail module is selected, the user is presented with the following options:

4.7.1	**Straight Tapered**	For calculation of straight tapered v-tail geometry.
4.7.2	**Cranked Canard**	For calculation of the equivalent straight tapered v-tail geometry from given cranked v-tail tail geometry.
4.7.3	**Volume Coefficient**	For calculation of the v-tail Volume Coefficient.
4.7.4	**Ruddervator/Tab**	For calculation of the ruddervator geometry.
4.7.5	**Chord Length**	For calculation of v-tail chord based on span wise location.
4.7.6	**Airfoil**	For calculation of airfoil parameters at the v-tail mean geometric chord.

4.7.7 **Exposed** For calculation of exposed v-tail parameters.

4.7.1 Straight Tapered

The method for determining the geometry of a straight tapered v-tail is identical to the method found in Section 4.4.1 of this manual.

4.7.2 Cranked V-Tail

The method for determining the geometry of a cranked v-tail is identical to the method found in Section 4.4.2 of this manual.

4.7.3 Volume Coefficient

This v-tail submodule calculates the volume coefficient of a v-tail planform. The methodology used to calculate the v-tail volume coefficient and related parameters is based on theory in Chapter 8 of Reference 2. After calculating the output parameters, the user may display the v-tail geometry by selecting the **Plot** option.

4.7.4 Ruddervator/Tab

In this submodule, the geometry of the ruddervator is added.

4.7.5 Chord Length

In this submodule, the chord length of the v-tail at any span wise location can be determined by using root chord length, taper ratio and the given span wise location.

4.7.6 Airfoil

In this submodule, the v-tail airfoil parameters at the v-tail mean geometric chord are calculated.

4.7.7 Exposed

In this submodule, the exposed v-tail parameters are calculated.

4.8 Ventral Fin Geometry

In this submodule, the ventral fin geometry is calculated.

4.9 Fuselage Geometry

The methodology used to calculate the fuselage geometry and fuselage related parameters is described in Chapter 4 of Reference 2. The user has to input the fuselage cross-section data. After calculating the output parameters, the user may display the fuselage geometry by selecting the **Plot** option.

4.10 Nacelle Geometry

The methodology used to calculate the nacelle geometry and nacelle related parameters is based on the fuselage geometry methods. The user has to input the nacelle cross-section data and define the sections of the nacelle. After calculating the output parameters, the user may display the nacelle geometry by selecting the **Plot** option.

4.11 Tailboom Geometry

The methodology used to calculate the tailboom geometry and tailboom related parameters is based on the fuselage geometry methods. The user has to input the tailboom cross-section data and define the sections of the tailboom. After calculating the output parameters, the user may display the tailboom geometry by selecting the **Plot** option.

4.12 Float Geometry

The methodology used to calculate the float geometry and float related parameters is based on the fuselage geometry methods. The user has to input the float cross-section data and define the sections of the float. After calculating the output parameters, the user may display the float geometry by selecting the **Plot** option.

4.13 Landing Gear

In this module the lateral angle between the airplane center of gravity and the landing gear. This

angle is useful in determining the risk of lateral tip-over on the ground. It also calculates the angle between the critical gear ground contact angle and the empty weight center of gravity and the current center of gravity. This angle is useful in determining the risk of longitudinal tip-over on the ground.

4.14 Canopy

This option is used to define the canopy geometry.

4.15 Store Geometry

The methodology used to calculate the store geometry and store related parameters is based on the fuselage geometry methods. The user has to input the store cross-section data and define the sections of the store. After calculating the output parameters, the user may display the store geometry by selecting the **Plot** option.

4.16 Pylon Geometry

This option is used to define the pylon geometry.

4.17 Propeller Geometry

This option is used to define the propeller geometry.

4.18 Airplane 3-View

This option is used to display the front, side and top view of the airplane.

4.19 Angles

This option all the pertinent angles used in the analysis.

4.20 Scale

This option is used to uniformly scale an airplane, using a user input scale factor. This feature is useful when analyzing a scale model, such as a wind tunnel model.

4.21 Translate

This option is used to translate the airplane in the X and Z directions.

4.22 Airfoil Folder

This option is used specify the location of the airfoil files.

4.23 AeroPack

This module can be used to export 3-Dimensional geometric data to the AeroPack drafting program (Reference 18). After selecting the **AeroPack** option, the following options are displayed:

- **Wing**
- **Horizontal Tail**
- **Vertical Tail**
- **Canard**
- **V-Tail**
- **Ventral Fin**
- **Fuselage**
- **Tailboom**
- **Nacelle**
- **Trail. Edge Flap**
- **Lead. Edge Flap**
- **Landing Gear**
- **Canopy**
- **Aileron**
- **Elevator**
- **Rudder**
- **Canardvator**
- **Ruddervator**
- **Spoiler**
- **Store**
- **Pylon**

- **Speed Brake**
- **Dorsal Fin**
- **Propeller**
- **Float**
- **Airfoil Folder**
- **Export Data**

The components that have been completely defined in the **Geometry** module can be selected for exporting.

4.24 Exporting to Shark/SharkFX-AP

After selecting the **Export Data** option, a dialog is displayed which allows the user to save the exported data as a *.geo file. Specify the folder and file name, and click ‘OK’ to save the file. The file can then be imported into Shark/SharkFX-AP. See the Shark/SharkFX-AP manual for import instructions.

5 Propulsion Module

5.1 General Description

In this Module the installed power and thrust of airplanes can be calculated. In addition to the installed power/thrust estimation, this module also provides options for:

- Inlet and nozzle sizing
- Estimation of inlet pressure recovery
- Estimation of inlet and nozzle drag

Calculations in this module are based on the methodologies outlined in Chapter 6 of Reference 7. Use of the Propulsion module options will be described in the following sections.

The assumption will be made that the following uninstalled propulsion characteristics are known:

- For piston engines: Shaft horsepower data for a specific flight condition.
- For turboprop and propfan engines: Shaft horsepower and thrust data for a specific flight condition.
- For jet engines: Thrust data and engine mass flow data for a specific flight condition.
- For propeller driven airplanes: Power coefficient and propeller efficiency or thrust coefficient for a specific flight condition.

Furthermore, the quantity of the engine power extraction needs to be known.

5.2 Type of Propulsion

Before the Propulsion module can be accessed, some basic parameters must be defined. The user is required to specify the type of engine from the engine dialog box. The options are as follows:

- Jet Engine For jet engine driven airplanes

- Piston Engine — For piston engine driven airplanes
- Propfan Engine — For propfan engine driven airplanes
- Turboprop Engine — For turboprop engine driven airplanes

In the case of a Jet Engine, a flight condition must be specified to define the type of jet from the following options:

- Subsonic Jet
- Supersonic Jet

5.3 Propulsion Main Window

After the propulsion type has been specified, a main menu is displayed. This menu provides the following options:

- **Power Extraction** — The options provided in this module are discussed in Section 5.4.
- **Inlet Design** — The options provided in this module are discussed in Section 5.5.
- **Nozzle Design** — The options provided in this module are discussed in Section 5.6.
- **Installed Data** — The options provided in this module are discussed in Section 5.7.

5.4 Power Extraction

In this submodule, the user can define and calculate the quantity of the total extracted power. This quantity is needed for installed thrust or installed power estimation. The next menu displays the following options:

- **Mechanical** — For estimation of extracted mechanical power. The user should prepare a list of those systems, which require mechanical power (i.e. fuel pumps, hydraulic pumps, etc.).
- **Electrical** — For estimation of extracted electrical power. To determine electrical power requirements, the user should prepare an "Electrical Power Load Profile" as described on page 320 in Reference 7.

- **Pneumatic** — For estimation of extracted pneumatic power (This option will not be offered for a piston engine selection). A list of airplane services that require bleed air as the source of power must be prepared.
- **Total** — For estimation of the power required for mechanical, electrical and pneumatic operation of the airplane.

5.5 Inlet Design

The purpose of the Inlet Design submodule is to estimate the streamtube cross-section at the inlet, the inlet pressure recovery, and the inlet extra drag. After invoking **Inlet Design**, the following options will be displayed:

- **Inlet Area** — To calculate the required inlet area.

  NOTE: The definitions of the inlet geometric parameters depending on engine and inlet choice are shown in Section 6.2 of Reference 7.
- **Pressure Loss** — To calculate the pressure loss in the inlet. Before invoking **Pressure Loss**, the inlet type must be specified in the engine dialog box as follows:
  - **O Plenum** — For all engine types except supersonic jet engines.
  - **O Straight Through** — For all engine types.
- **Manifold Pressure** — To calculate the manifold absolute pressure.

5.6 Nozzle Design

In this submodule, some nozzle design objectives are provided. After invoking **Nozzle Design**, the exhaust exit area window appears, asking for take-off shaft horsepower.

5.7 Installed Data

In this submodule, the installed performance of the propulsion system can be estimated for a single set of conditions. In case there is no engine and/or propeller data file available, the user

can estimate the installed characteristics for a single condition. This requires uninstalled engine/propeller performance data. It is suggested that the manufacturer's data be used.

5.8 Propeller

In this submodule, propeller performance maps can be imported and used to determine the efficiency of the propeller under various flight conditions. The efficiency can also be plotted as a function of speed and altitude.

6 Stability & Control Module

6.1 General Description

Stability and Control consists of two submodules: **Derivatives** and **Analysis**. The purpose of the **Derivatives** submodule is to compute the non-dimensional aerodynamic stability and control derivatives and hingemoment derivatives for a rigid airplane in a given flight condition (i.e., for a given weight, altitude, and speed). The purpose of the **Analysis** submodule is to help the user rapidly determine whether or not a proposed aircraft configuration will have satisfactory stability and control characteristics. The Stability & Control module also allows the user to calculate the required vertical tail, canard and/or horizontal tail surface area needed to satisfy user defined stability and control characteristics.

The mathematical equations used to compute stability and control derivatives can be found in Reference 7.

6.2 Stability & Control Main Window

After selecting the **Stab. & Control** module, the user can select from the two options displayed:

- **Derivatives** — For estimation of all longitudinal and lateral-directional stability, longitudinal and lateral-directional control, and control surface hingemoment derivatives. The options provided in this module are discussed in Sections 6.3 through 6.8.
- **Analysis** — For estimation of inherent airplane stability and control surface sizing. The options provided in this module are discussed in Sections 6.9 through 6.13.

Once the **Derivatives** button has been selected in the main window, a new menu appears with six options, which are discussed in the following sections:

6.3 **Long. Stability** — For estimation of the longitudinal stability derivatives

6.4	**Lat-Dir Stability**	For estimation of the lateral-directional stability derivatives
6.5	**Long. Control**	For estimation of the longitudinal control derivatives
6.6	**Lat-Dir Control**	For estimation of the lateral-directional control derivatives
6.7	**Hingemoment**	For estimation of the control surface and trim tab hingemoment derivatives
6.8	**Recalculate All**	For quick re-calculation of all derivatives due to changes in flight condition

When the **Analysis** button has been selected in the main window, a new menu appears with three options that are discussed in the following sections:

6.9	**Class I**	For estimation of the Class I empennage analysis
6.10	**Class II**	For estimation of the airplane longitudinal and lateral-directional trim characteristics
6.11	**Stick Free Static Margin**	For estimation of stick free Static Margin.
6.12	**Stick Force**	For estimation of stick force and stick force-speed gradient.
6.13	**Aileron Force**	For estimation of the aileron stick or wheel force.
6.14	**Rudder Force**	For estimation of the rudder pedal force and rudder pedal force-vs-sideslip angle gradient.
6.15	**Wing Location**	For quick estimation of the wing location and its effect on stability.

6.3 Longitudinal Stability Derivatives

When the **Long. Stability** has been selected, a menu appears with five longitudinal stability derivative submodules. These submodules are:

6.3.1	**Steady State**	For estimation of the steady state lift, drag, moment and thrust coefficients
6.3.2	**Speed**	For estimation of the speed derivatives
6.3.3	**Angle of Attack**	For estimation of the angle-of-attack derivatives
6.3.4	**A.O.A. Rate**	For estimation of the rate of angle-of-attack derivatives
6.3.5	**Pitch Rate**	For estimation of the pitch rate derivatives

For certain submodules, the user must define the lifting surfaces in the Airplane Configuration dialog box (See Section 2.2.3, Figure 2.16).

6.3.1 Steady State Coefficients

This module can be used to calculate steady state lift, drag, moment, and thrust derivatives. When the **Steady State** button is selected, a new menu appears with the following options:

- C_{D_1} This submodule can be used to estimate the steady state drag coefficient.
- C_{L_1} This submodule can be used to estimate the steady state lift coefficient.
- C_{m_1} This submodule can be used to estimate the steady state pitching moment coefficient.
- $C_{T_{x_1}}$ This submodule can be used to estimate the steady state thrust force coefficient. This option is not available if "None" is specified as the powerplant.
- $C_{m_{T_1}}$ This submodule can be used to estimate the steady state thrust pitching moment coefficient. This option is not available if "None" is specified as the powerplant.

6.3.2 Speed Derivatives

The methodology used to calculate the speed-related derivatives can be found in Section 10.2.1 of Reference 7. Once the **Speed** button is selected, a new menu appears with the following five speed related derivative options:

- C_{D_u} This submodule can be used to estimate the drag-coefficient-due-to-speed derivative.
- C_{L_u} This submodule can be used to estimate the lift-coefficient-due-to-speed derivative.

- C_{m_u} This submodule can be used to estimate the pitching-moment-coefficient-due-to-speed derivative.
- $C_{T_{x_u}}$ This submodule can be used to estimate the thrust-force-coefficient-due-to-speed derivative. This option is not available if "None" is specified as the powerplant.
- C_{mT_u} This submodule can be used to estimate the thrust-pitching-moment-coefficient-due-to-speed derivative. This option is not available if "None" is specified as the powerplant.

NOTE: There are two methods of entering values of the aerodynamic center shift due to the fuselage, nacelles, stores, floats and tailbooms. The user may:

1) Enter the values of the aerodynamic center shift due to the fuselage, nacelles, stores and tailbooms in terms of the wing mean geometric chord in the C_{m_u} submodule if these values are known.
2) Use the **Aerodynamic Center** module to calculate the values for the aerodynamic center shift due to the fuselage, nacelles, stores, floats and tailbooms in terms of the wing mean geometric chord. If the user chooses to first use the **Aerodynamic Center** module, the values for the aerodynamic center shift will automatically be transferred into the C_{m_u} submodule input. For a complete description of the **Aerodynamic Center** module, see Part III, Section 2.6 of this user's manual.

6.3.3 Angle-of-Attack Derivatives

The methodology used to calculate the angle-of-attack related derivatives can be found in Section 10.2.2 of Reference 7. Once the **Angle of Attack** button is selected, a new menu appears with the following angle-of-attack related derivative options:

- C_{D_α} This submodule can be used to estimate the drag-coefficient-due-to-angle-of-attack derivative.

- C_{L_α} This submodule can be used to estimate the lift-coefficient-due-to-angle-of-attack derivative.
- C_{m_α} This submodule can be used to estimate the pitching-moment-coefficient-due-to-angle-of-attack derivative.
- $C_{m_{T_\alpha}}$ This submodule can be used to estimate the thrust pitching moment coefficient due to angle of attack derivative. This option is only available for propeller-powered airplanes.

NOTE: There are two ways to enter values for the aerodynamic center shift due to the fuselage, nacelles, stores, floats and tailbooms. The user may:

1) Enter the values for the aerodynamic center shift, in terms of the wing mean geometric chord, due to the fuselage, nacelles, stores, floats and tailbooms in the C_{m_α} submodule if these values are known.
2) Use the **Aerodynamic Center** module to calculate the values of the aerodynamic center shift due to the fuselage, nacelles, stores, floats and tailbooms in terms of the wing mean geometric chord. If the user chooses to use the **Aerodynamic Center** module first, the values for the aerodynamic center shift will automatically be transferred into the C_{m_α} submodule input. For a complete description of the **Aerodynamic Center** module, see Part III, Section 2.6 of this user's manual.

6.3.4 Rate of Angle-of-Attack Derivatives

The methodology used to calculate the rate of angle-of-attack related derivatives can be found in Section 10.2.3 of Reference 7. Once the **A.O.A. Rate** button is selected, a new menu appears with the following rate of angle-of-attack related derivative options:

- $C_{D_{\dot{\alpha}}}$ In preliminary design, the drag-coefficient-due-to-rate-of-angle-of-attack derivative is assumed to be negligible and will therefore not be calculated. The program automatically sets this derivative equal to zero and no additional menus appear on the screen.

- $C_{L_{\dot{\alpha}}}$ This submodule can be used to estimate the lift-coefficient-due-to-rate-of-angle-of-attack derivative.
- $C_{m_{\dot{\alpha}}}$ This submodule can be used to estimate the pitching-moment-coefficient-due-to-rate-of-angle-of-attack derivative.

6.3.5 Pitch Rate Derivatives

The methodology used to calculate the pitch-rate related derivatives can be found in Section 10.2.7 of Reference 7. Once the **Pitch Rate** button is selected, a new menu appears with the following pitch rate related derivative options:

- C_{D_q} In preliminary design the drag-coefficient-due-to-pitch-rate derivative is assumed to be negligible and will therefore not be calculated. The program automatically sets this derivative equal to zero and no additional menus appear on the screen.
- C_{L_q} For estimation of the lift-coefficient-due-to-pitch-rate derivative.
- C_{m_q} For estimation of the pitching-moment-coefficient-due-to-pitch-rate derivative.

6.4 Lateral-Directional Stability Derivatives

Once the **Lat-Dir Stability** option has been selected, another menu appears with four lateral-directional stability derivative submodules. These four submodules are:

6.4.1 **Sideslip** For estimation of the angle-of-sideslip derivatives.

6.4.2 **Sideslip Rate** For estimation of the rate of angle-of-sideslip derivatives.

6.4.3 **Roll Rate** For estimation of the roll rate derivatives.

6.4.4 **Yaw Rate** For estimation of the yaw rate derivatives.

For certain submodules, the user must define the longitudinal control surface in the Airplane Configuration dialog box (See Section 2.2.3, Figure 2.16).

In addition, the user must also define the vertical tail and the number of vertical tail(s) in the Airplane Configuration dialog box (See Section 2.2.3, Figure 2.16).

6.4.1 Angle-of-Sideslip Derivatives

The methodology used to calculate the sideslip related derivatives can be found in Section 10.2.4 of Reference 7. Once the **Sideslip** button has been selected, a new menu appears with the following angle-of-sideslip related derivative options:

- C_{y_β} This submodule can be used to estimate the side-force-coefficient-due-to-sideslip derivative.
- C_{l_β} This submodule can be used to estimate the rolling-moment-coefficient-due-to-sideslip derivative.
- C_{n_β} This submodule can be used to estimate the yawing-moment-coefficient-due-to-sideslip derivative.
- $C_{y_{T\beta}}$ This submodule can be used to estimate thrust side force coefficient due to sideslip Derivative.
- $C_{n_{T_\beta}}$ This submodule can be used to estimate the thrust-yawing-moment-coefficient-due-to-sideslip derivative.

6.4.2 Rate of Angle-of-Sideslip Derivatives

The methodology used to calculate the rate of sideslip related derivatives can be found in Section 10.2.5 of Reference 7. When the **Sideslip Rate** button is selected, a new menu appears with the following three rate of sideslip related derivative options:

- $C_{y_{\dot\beta}}$ This submodule can be used to estimate the side-force-coefficient-due-to-rate-of-sideslip derivative.
- $C_{l_{\dot\beta}}$ This submodule can be used to estimate the rolling-moment-coefficient-due-to-rate-of-sideslip derivative.

- $C_{n_{\dot{\beta}}}$ This submodule can be used to estimate the yawing-moment-coefficient-due-to-rate-of-sideslip derivative.

6.4.3 Roll Rate Derivatives

The methodology used to calculate the roll rate related derivatives can be found in Section 10.2.6 of Reference 7. Once the **Roll Rate** button is selected, a new menu appears with the following three roll rate related derivative options:

- C_{y_p} This submodule can be used to estimate the side-force-coefficient-due-to-roll-rate derivative.
- C_{l_p} This submodule can be used to estimate the rolling-moment-coefficient-due-to-roll-rate derivative.
- C_{n_p} This submodule can be used to estimate the yawing-moment-coefficient-due-to-roll-rate derivative.

6.4.4 Yaw Rate Derivatives

The methodology used to calculate the yaw rate related derivatives can be found in Section 10.2.8 of Reference 7. When the **Yaw Rate** button is selected, a new menu appears with the following three yaw rate related derivative options:

- C_{y_r} This submodule can be used to estimate the side-force-coefficient-due-to-yaw-rate derivative.
- C_{l_r} This submodule can be used to estimate the rolling-moment-coefficient-due-to-yaw-rate derivative.
- C_{n_r} This submodule can be used to estimate the yawing-moment-coefficient-due-to-yaw-rate derivative.

6.5 Longitudinal Control Derivatives

The **Long. Control** submodule has six longitudinal control surface and trim tab derivative submodules. These twelve submodules are:

6.5.1	**Stabilizer**	For estimation of the stabilizer control derivatives
6.5.2	**Elevator**	For estimation of the elevator control derivatives
6.5.3	**Elevator Tab**	For estimation of the elevator tab control derivatives
6.5.4	**Canard**	For estimation of the canard control derivatives
6.5.5	**Canardvator**	For estimation of the canardvator control derivatives
6.5.6	**Canardvator Tab**	For estimation of the canardvator tab control derivatives
6.5.7	**V-Tail**	For estimation of the v-tail control derivatives
6.5.8	**Ruddervator**	For estimation of the ruddervator control derivatives
6.5.9	**Ruddervator Tab**	For estimation of the ruddervator tab control derivatives
6.5.10	**Flying Wing**	For estimation of the flying wing control derivatives
6.5.11	**Elevon**	For estimation of the elevon control derivatives
6.5.12	**Elevon Tab**	For estimation of the elevon tab control derivatives

6.5.1 Stabilizer Related Derivatives

The methodology used to calculate the horizontal stabilizer related derivatives can be found in Section 10.3.1 of Reference 7. Once the **Stabilizer** button is selected, a new menu appears with the following three stabilizer-related derivative options:

- $C_{D_{i_h}}$ This submodule can be used to estimate the drag-coefficient-due-to-horizontal-stabilizer-incidence derivative.
- $C_{L_{i_h}}$ This submodule can be used to estimate the lift-coefficient-due-to-horizontal-stabilizer-incidence derivative.
- $C_{m_{i_h}}$ This submodule can be used to estimate the pitching-moment-coefficient-due-to-horizontal-stabilizer-incidence derivative.

6.5.2 Elevator Related Derivatives

The methodology used to calculate the elevator-related derivatives can be found in Section 10.3.2 of Reference 7. When the **Elevator** button is selected, a new menu appears with the following three elevator-related derivative options:

- $C_{D_{\delta_e}}$ This submodule can be used to estimate the drag-coefficient-due-to-elevator-deflection derivative.
- $C_{L_{\delta_e}}$ This submodule can be used to estimate the lift-coefficient-due-to-elevator-deflection derivative.
- $C_{m_{\delta_e}}$ This submodule can be used to estimate the pitching-moment-coefficient-due-to-elevator-deflection derivative.

6.5.3 Elevator Tab Related Derivatives

The methodology used to calculate the elevator tab related derivatives can be found in Section 10.3.2 of Reference 7. When the **Elevator Tab** button is selected, a new menu appears with the following two elevator tab related derivative options:

- $C_{L_{\delta_{et}}}$ This submodule can be used to estimate the lift-coefficient-due-to-elevator-tab-deflection derivative.
- $C_{m_{\delta_{et}}}$ This submodule can be used to estimate the pitching-moment-coefficient-due-to-elevator-tab-deflection derivative.

6.5.4 Canard Related Derivatives

The methodology used to calculate the canard-related derivatives can be found in Section 10.3.3 of Reference 7. Once the **Canard** button is selected, a new menu appears with the following three canard-related derivative options:

- $C_{D_{i_c}}$ This submodule can be used to estimate the drag-coefficient-due-to-canard-incidence derivative.
- $C_{L_{i_c}}$ This submodule can be used to estimate the lift-coefficient-due-to-canard-incidence derivative.
- $C_{m_{i_c}}$ This submodule can be used to estimate the pitching-moment-coefficient-due-to-canard-incidence derivative.

6.5.5 Canardvator Related Derivatives

The methodology used to calculate the canardvator-related derivatives can be found in Section 10.3.4 of Reference 7. When the **Canardvator** button is selected, a new menu appears with the following three canardvator-related derivative options:

- $C_{D_{\delta_{cv}}}$ This submodule can be used to estimate the drag-coefficient-due-to-canardvator-deflection derivative.
- $C_{L_{\delta_{cv}}}$ This submodule can be used to estimate the lift-coefficient-due-to-canardvator-deflection derivative.
- $C_{m_{\delta_{cv}}}$ This submodule can be used to estimate the pitching-moment-coefficient-due-to-canardvator-deflection derivative.

6.5.6 Canardvator Tab Related Derivatives

The methodology used to calculate the canardvator tab related derivatives can be found in Section 10.3.4 of Reference 7. When the **Canardvator Tab** button is selected, a new menu appears with the following two canardvator tab related derivative options:

- $C_{L_{\delta_{ct}}}$ This submodule can be used to estimate the lift-coefficient-due-to-canardvator-tab-deflection derivative.
- $C_{m_{\delta_{ct}}}$ This submodule can be used to estimate the pitching-moment-coefficient-due-to-canardvator-tab-deflection derivative.

6.5.7 V-Tail Related Derivatives

The methodology used to calculate the v-tail-related derivatives is based on theory in Section 10.3.1 of Reference 7. Once the **V-Tail** button is selected, a new menu appears with the following three v-tail-related derivative options:

- $C_{D_{i_{vee}}}$ This submodule can be used to estimate the drag-coefficient-due-to-v-tail-incidence derivative.

- $C_{L_{i_{vee}}}$ This submodule can be used to estimate the lift-coefficient-due-to-v-tail-incidence derivative.
- $C_{m_{i_{vee}}}$ This submodule can be used to estimate the pitching-moment-coefficient-due-to-v-tail-incidence derivative.

6.5.8 Ruddervator Related Derivatives

The methodology used to calculate the ruddervator-related derivatives is based on theory in Sections 10.3.2 and 10.3.8 of Reference 7. When the **Ruddervator** button is selected, a new menu appears with the following three ruddervator-related derivative options:

- $C_{D_{\delta_{rv}}}$ This submodule can be used to estimate the drag-coefficient-due-to-ruddervator-deflection derivative.
- $C_{L_{\delta_{rv}}}$ This submodule can be used to estimate the lift-coefficient-due-to-ruddervator-deflection derivative.
- $C_{m_{\delta_{rv}}}$ This submodule can be used to estimate the pitching-moment-coefficient-due-to-ruddervator-deflection derivative.

6.5.9 Ruddervator Tab Related Derivatives

The methodology used to calculate the ruddervator tab related derivatives is based on theory in Sections 10.3.2 and 10.3.8 of Reference 7. When the **Ruddervator Tab** button is selected, a new menu appears with the following two ruddervator tab related derivative options:

- $C_{L_{\delta_{rvt}}}$ This submodule can be used to estimate the lift-coefficient-due-to-ruddervator-tab-deflection derivative.
- $C_{m_{\delta_{rvt}}}$ This submodule can be used to estimate the pitching-moment-coefficient-due-to-ruddervator-tab-deflection derivative.

6.5.10 Flying Wing Related Derivatives

The methodology used to calculate the flying wing-related derivatives is based on theory in

Section 10.2.2.1 of Reference 7. Once the **Flying Wing** button is selected, a new menu appears with the following three flying wing-related derivative options:

- $C_{D_{i_w}}$ This submodule can be used to estimate the drag-coefficient-due-to-flying wing-incidence derivative.
- $C_{L_{i_w}}$ This submodule can be used to estimate the lift-coefficient-due-to-flying wing-incidence derivative.
- $C_{m_{i_w}}$ This submodule can be used to estimate the pitching-moment-coefficient-due-to-flying wing-incidence derivative.

6.5.11 Elevon Related Derivatives

The methodology used to calculate the elevon-related derivatives is based on theory in Section 10.3.5 of Reference 7. When the **Elevon** button is selected, a new menu appears with the following three elevon-related derivative options:

- $C_{D\delta_{el}}$ This submodule can be used to estimate the drag-coefficient-due-to-elevon-deflection derivative.
- $C_{L_{\delta_{el}}}$ This submodule can be used to estimate the lift-coefficient-due-to-elevon-deflection derivative.
- $C_{m_{\delta_{el}}}$ This submodule can be used to estimate the pitching-moment-coefficient-due-to-elevon-deflection derivative.

6.5.12 Elevon Tab Related Derivatives

The methodology used to calculate the elevon tab related derivatives derivatives is based on theory in Section 10.3.5 of Reference 7. When the **Elevon Tab** button is selected, a new menu appears with the following two elevon tab related derivative options:

- $C_{L_{\delta_{elt}}}$ This submodule can be used to estimate the lift-coefficient-due-to-elevon-tab-deflection derivative.

- $C_{m_{\delta_{elt}}}$ This submodule can be used to estimate the pitching-moment-coefficient-due-to-elevon-tab-deflection derivative.

6.6 Lateral-Directional Control Derivatives

The Lateral-Directional Control submodule has six lateral-directional control surface and trim tab derivative submodules. These eight submodules are:

6.6.1	**Aileron**	For estimation of the aileron derivatives
6.6.2	**Aileron Tab**	For estimation of the aileron tab derivatives
6.6.3	**Spoiler**	For estimation of the spoiler derivatives
6.6.4	**Vert. Tail**	For estimation of the vertical tail derivatives
6.6.5	**Rudder**	For estimation of the rudder derivatives
6.6.6	**Rudder Tab**	For estimation of the rudder tab derivatives
6.6.7	**V-Tail**	For estimation of the v-tail derivatives.
6.6.8	**Ruddervator**	For estimation of the ruddervator derivatives
6.6.9	**Ruddervator Tab**	For estimation of the ruddervator tab derivatives
6.6.10	**Diff. Stabilizer**	For estimation of the differential stabilizer derivatives

6.6.1 Aileron Related Derivatives

The methodology used to calculate the aileron-related derivatives can be found in Section 10.3.5 of Reference 7. Once the **Aileron** button is selected, a new menu appears with the following three aileron-related derivative options:

- $C_{y_{\delta_a}}$ In preliminary design the side-force-coefficient-due-to-aileron derivative is assumed to be negligible and will therefore not be calculated. The program sets this derivative equal to zero and no additional menus appear on the screen.
- $C_{l_{\delta_a}}$ This submodule can be used to estimate the rolling-moment-coefficient-due-to-aileron derivative.
- $C_{n_{\delta_a}}$ This submodule can be used to estimate the yawing-moment-coefficient-due-to-aileron derivative.

6.6.2 Aileron Tab Related Derivatives

The methodology used to calculate the aileron tab related derivatives can be found in Section 10.3.5 of Reference 7. Once the **Aileron Tab** button is selected, a new menu appears with the following three aileron tab related derivative options:

- $C_{y_{\delta_{at}}}$ In preliminary design the side-force-coefficient-due-to-aileron-tab derivative is assumed to be negligible and will therefore not be calculated. The program sets this derivative equal to zero and no additional menus appear on the screen.
- $C_{l_{\delta_{at}}}$ This submodule can be used to estimate the rolling-moment-coefficient-due-to-aileron-tab derivative.
- $C_{n_{\delta_{at}}}$ This submodule can be used to estimate the yawing-moment-coefficient-due-to-aileron-tab derivative.

6.6.3 Spoiler Related Derivatives

Before accessing the spoiler input/output window, the user must define the type of spoiler in the Airplane Configuration dialog box (See Section 2.2.3, Figure 2.16).

The methodology used to calculate the spoiler-related derivatives can be found in Section 10.3.6 of Reference 7. When the **Spoiler** button is selected, a new menu appears with the following three spoiler-related derivative options:

- $C_{y_{\delta_{sp}}}$ In preliminary design the side-force-coefficient-due-to-spoiler derivative is assumed to be negligible and will therefore not be calculated. The program sets this derivative equal to zero and no additional menus appear on the screen.
- $C_{l_{\delta_{sp}}}$ This submodule can be used to estimate the rolling-moment-coefficient-due-to-spoiler derivative.

- $C_{n_{\delta_{sp}}}$ This submodule can be used to estimate the yawing-moment-coefficient-due-to-spoiler derivative.

6.6.4 Vertical Tail Related Derivatives

Once the **Vert. Tail** button is selected, a new menu appears with the following three vertical tail related derivative options:

- $C_{y_{i_v}}$ This submodule can be used to estimate the sideforce-coefficient-due-to-vertical-tail-incidence derivative.
- $C_{l_{i_v}}$ This submodule can be used to estimate the rolling-moment-coefficient-due-to-vertical-tail-incidence derivative.
- $C_{n_{i_v}}$ This submodule can be used to estimate the yawing-moment-coefficient-due-to-vertical-tail-incidence derivative.

6.6.5 Rudder Related Derivatives

The methodology used to calculate the rudder-related derivatives is based on theory in Sections 10.3.2 and 10.3.8 of Reference 7. Once the **Rudder** button is selected and the vertical tail configuration has been chosen, a new menu appears with the following three rudder-related derivative options:

- $C_{y_{\delta_r}}$ This submodule can be used to estimate the side-force-coefficient-due-to-rudder derivative.
- $C_{l_{\delta_r}}$ This submodule can be used to estimate the rolling-moment-coefficient-due-to-rudder derivative.
- $C_{n_{\delta_r}}$ This submodule can be used to estimate the yawing-moment-coefficient-due-to-rudder derivative.

6.6.6 Rudder Tab Related Derivatives

The methodology used to calculate the rudder tab related derivatives can be found in Section 10.3.8 of Reference 7. Once the **Rudder Tab** button is selected and the vertical tail

configuration has been chosen, a new menu appears with the following three rudder tab related derivative options:

- $C_{y_{\delta_{rt}}}$ This submodule can be used to estimate the side-force-coefficient-due-to-rudder-tab derivative.
- $C_{l_{\delta_{rt}}}$ This submodule can be used to estimate the rolling-moment-coefficient-due-to-rudder-tab derivative.
- $C_{n_{\delta_{rt}}}$ This submodule can be used to estimate the yawing-moment-coefficient-due-to-rudder-tab derivative.

6.6.7 V-Tail Related Derivatives

Once the **V-Tail** button is selected, a new menu appears with the following three v-tail related derivative options:

- $C_{y_{i_{vee}}}$ This submodule can be used to estimate the sideforce-coefficient-due-to-v-tail-incidence derivative.
- $C_{l_{i_{vee}}}$ This submodule can be used to estimate the rolling-moment-coefficient-due-to-v-tail-incidence derivative.
- $C_{n_{i_{vee}}}$ This submodule can be used to estimate the yawing-moment-coefficient-due-to-v-tail-incidence derivative.

6.6.8 Ruddervator Related Derivatives

The methodology used to calculate the ruddervator related derivatives can be found in Section 10.3.7 of Reference 7. Once the **Ruddervator** button is selected, a new menu appears with the following three ruddervator-related derivative options:

- $C_{y_{rv}}$ In preliminary design the side-force-coefficient-due-to-ruddervator derivative is assumed to be negligible and will therefore not be calculated. The program sets this derivative equal to zero and no additional menus appear on the screen.

- $C_{l_{rv}}$ This submodule can be used to estimate the rolling-moment-coefficient-due-to-ruddervator derivative.
- $C_{n_{rv}}$ This submodule can be used to estimate the yawing-moment-coefficient-due-to-ruddervator derivative. For the estimation of this derivative, no reliable preliminary design methods are available.

6.6.9 Ruddervator Tab Related Derivatives

The methodology used to calculate the ruddervator tab related derivatives is based on theory in Sections 10.3.2 and 10.3.8 of Reference 7. Once the **Ruddervator** button is selected, a new menu appears with the following three ruddervator tab-related derivative options:

- $C_{y_{rvt}}$ In preliminary design the side-force-coefficient-due-to- ruddervator tab derivative is assumed to be negligible and will therefore not be calculated. The program sets this derivative equal to zero and no additional menus appear on the screen.
- $C_{l_{rvt}}$ This submodule can be used to estimate the rolling-moment-coefficient-due-to- ruddervator tab derivative.
- $C_{n_{rvt}}$ This submodule can be used to estimate the yawing-moment-coefficient-due-to- ruddervator tab derivative. For the estimation of this derivative, no reliable preliminary design methods are available.

6.6.10 Differential Stabilizer Related Derivatives

The methodology used to calculate the differential stabilizer related derivatives can be found in Section 10.3.7 of Reference 7. Once the **Diff. Stabilizer** button is selected, a new menu appears with the following three differential stabilizer-related derivative options:

- $C_{y_{i_h}}$ In preliminary design the side-force-coefficient-due-to-differential-stabilizer derivative is assumed to be negligible and will therefore

not be calculated. The program sets this derivative equal to zero and no additional menus appear on the screen.

- $C_{l_{i_h}}$ This submodule can be used to estimate the rolling-moment-coefficient-due-to-differential-stabilizer derivative.
- $C_{n_{i_h}}$ This submodule can be used to estimate the yawing-moment-coefficient-due-to-differential-stabilizer derivative. For the estimation of this derivative, no reliable preliminary design methods are available.

6.7 Hingemoment Derivatives

The **Hingemoment** submodule is used to determine the hingemoment coefficient derivatives of the elevator, rudder, aileron, canardvator, ruddervator, elevator tab, rudder tab, aileron tab, canardvator tab, and ruddervator tab. Note that the elevon and elevon tab hingemoments are calculated in the aileron, and aileron tab hingemoment module. The methodology for the hingemoment calculations is found in Section 10.4 of Reference 7. Before accessing any control surface and trim tab hingemoment derivative input/output window, the user must define the lifting surface tip shape from the following options in the Control Surfaces Configuration dialog box (See Figure 2.18).

- Elliptic Tip For a horizontal stabilizer/vertical tail/wing/canard with rounded or elliptic tips.
- Square Tip For a horizontal stabilizer/vertical tail/wing/canard with square tips.

Once the desired lifting surface tip shape is selected, the user may define the airfoil nose shape from the following options:

- Round Nose For control surface with a rounded nose
- Elliptic Nose For control surface with an elliptic nose
- Sharp Nose For control surface with a sharp or pointed nose
- Round Low Drag For control surface with an aerodynamically shaped low drag nose

Once the nose shape is selected, the user must define the type of balance for the control surface from the following options:

- Nose Balance — Control surface is balanced solely with the nose
- Nose/Horn Balance — Control surface is balanced with a horn or a combination of horn and nose

If the control surface is defined with a horn (i.e. Nose/Horn Balance), the user must define the horn type from the following options:

- Unshielded Horn — For a horn that is not protected from the free stream air
- Fully Shielded Horn — For a horn fully protected from the free stream air
- Part Shielded Horn — For a horn partially protected from the free stream air

Finally, if the horn is fully or partially shielded (i.e. Fully Shielded Horn or Part Shielded Horn), the user is given the following options to define the horn nose:

- Blunt Nose — For a horn with a blunt nose
- Elliptic Nose — For a horn with an elliptic nose

6.8 Recalculate All

This module allows the user to recalculate all of the stability and control derivatives by pressing calculate once. The user can change a parameter in the input and view its effect on the stability and control derivatives. A stability or control derivative will only be recalculated if all of its associated input is defined.

6.9 Class I Stability and Control/Empennage Sizing Analysis

The methodology used to analyze the Stability and Control characteristics can be found in Chapter 11 of Reference 2. When the **Class I** submodule has been selected, a new menu appears on the screen with three Class I Stability and Control/Empennage Sizing options:

6.8.1 **Longitudinal** — For longitudinal stability and empennage sizing

6.8.2 **Directional** — For directional stability and empennage sizing

6.8.3 **One Engine Out** For minimum control speed with one engine inoperative stability/empennage sizing

Other important stability and control characteristics such as trimmability, take-off rotation, crosswind controllability and a variety of dynamic stability considerations are not covered by the Class I method.

6.9.1 Static Longitudinal Stability

The **Longitudinal** submodule is used to perform computations related to the static longitudinal stability of an airplane. The methodology used to calculate the static longitudinal stability can be found in Section 11.1 of Reference 2.

When the **Longitudinal** submodule is selected, another menu appears with three stability types. These stability types are:

- **Inherent** Represents inherent stability, which is required of all airplanes that do not rely on a feedback augmentation system for their stability. The user has two options in this submodule:
  - **Static Margin** For calculation of static margin for a given canard and horizontal tail area
  - **Surface Area** For calculation of canard and horizontal tail area for a given static margin
- **De Facto** Represents de facto stability, which is required of all airplanes that are stable only with a feedback augmentation system in place. If the static margin exceeds the value of 0.05, no feedback augmentation system is required and the feedback gain in this condition will be set to zero.
- **Volume Method** Represents the sizing method based on volume coefficients. The user has two options in this submodule:
  - **Quarter Chord** For sizing the horizontal tail, canard, or v-tail based on lifting surface position in reference to the wing

- **A.C. – C.G.** For sizing the horizontal tail, canard, or v-tail based on aerodynamic center location

Before any of the above options can be selected, the user must define one of three types of airplane configurations in the Airplane Configuration dialog box (See Section 2.2.3, Figure 2.16).

6.9.2 Static Directional Stability

The **Directional** submodule is used to perform all the computations related to the static directional stability. The methodology used to calculate the static directional stability can be found in Section 11.2 of Reference 2.

Once the **Directional** submodule has been selected, a menu appears with three stability types. The user must define the number of vertical tail surfaces in the Airplane Configuration dialog box to use these submodules. These stability types are:

- **Inherent** Represents inherent stability, which is required of all airplanes that do not rely on a feedback augmentation system for their stability. The user has two options in this submodule:
  - C_{n_β} for calculation of C_{n_β} for a given vertical tail area
  - **Surface Area** for calculation of vertical tail area for a given C_{n_β}
- **De Facto** Represents de facto stability, which is required of all airplanes that are stable only with a feedback augmentation system in place. If C_{n_β} exceeds the value of 0.001 deg^{-1}, no feedback augmentation system is required and the feedback gain in this condition will be set to zero.
- **Volume Method** Represents the sizing method based on volume coefficients. The user has two options in this submodule:
  - **Quarter Chord** For sizing the horizontal tail, canard, or v-tail based on lifting surface position in reference to the wing

O A.C. – C.G. For sizing the horizontal tail, canard, or v-tail based on aerodynamic center location

6.9.3 Minimum Controllable Speed with One Engine Inoperative Stability

The **One Engine Out** submodule is used to check the size of the vertical tail for the case of climb with one engine inoperative and applies only to airplanes with more than one engine. The rudder deflection required to maintain controllability in the one engine out condition at minimum controllable speed is also calculated. The methodology used to calculate one engine inoperative stability can be found in Section 11.3 of Reference 2.

6.10 Class II Trim Analysis

The methodology used to analyze the longitudinal and lateral-directional trim characteristics can be found in Chapter 4 of Reference 11. When the **Class II** button is selected, the following options appear on the screen:

6.10.1 **Trim Diagram** For determination of longitudinal trim characteristics.

6.10.2 **Long. Trim** For determination of elevator stick (or control wheel) forces.

6.10.3 **Lat-Dir Trim** For determination of aileron stick (or control wheel) forces and rudder pedal forces.

6.10.4 **T.O. Rotation** For determination of the horizontal tail area required for rotation.

6.10.5 **Trimmed Lift (T from D)** For determination of the trimmed lift coefficients where thrust is calculated from the drag.

6.10.6 **Trimmed Lift (T = Const)** For determination of the trimmed lift coefficients where thrust is kept constant.

6.10.1 Trim Diagram Analysis

The **Trim Diagram** submodule is used to determine the trim characteristics of an airplane. The methodology used to generate the trim diagram can be found in Chapter 4 of Reference 11, and Section 8.3 of Reference 7.

The user has to select between **Class I, Class II** or **Wind Tunnel** Drag Polar modules (see Section 2.4) from the Flight Condition dialog window. It is not possible to generate a trim diagram without defining all input data. The input window is different for each aircraft configuration and moving surface combination.

When all the input parameters are defined, the trim diagram can be displayed by selecting the **Plot** button. The plot may be altered using the conventional plot control buttons (Section II 2.1.4).

6.10.2 Longitudinal Trim

The Longitudinal Trim submodule is used to solve the longitudinal equations for trim. The methods in this module do not allow for canard or three surface airplanes. The user must define a horizontal tail in the Airplane Configuration dialog box.

The input data required for the longitudinal trim submodule include the drag polar of the airplane. The user has to select between **Class I** or **Class II** or **Wind Tunnel** Drag Polar modules (see Section 2.4) from the Flight Condition dialog window. The longitudinal trim calculations are executed by solving the following equations simultaneously:

- Drag equation
- Lift equation
- Pitching moment equation
- Stick force equation

The four equations contain six variables. Therefore, the user must define two of the following variables as control variables:

- α Airplane angle of attack.
- γ Flight path angle.
- δ_e Elevator deflection angle.
- $\delta_{et_{trim}}$ Additional elevator trim tab deflection angle required to trim.
- i_h Stabilizer incidence angle.
- F_s Stick force.

If the angle of attack is selected as the first control variable, the flight path angle cannot be

selected as the second variable. The remaining four variables not defined by the user as control variables are calculated and displayed in the output along with various gradients important to flying qualities.

6.10.3 Lateral-Directional Trim

The Lateral-Directional Trim submodule is used to solve the lateral-directional equations for trim. Solving the following equations simultaneously completes the lateral-directional trim calculations for either flight condition:

- Side force equation
- Rolling moment equation
- Yawing moment equation
- Uudder pedal force equation
- Aileron stick (or wheel) force equation

The five equations contain eight variables, so, three of the following variables must be defined:

- ϕ Bank angle
- β Sideslip angle
- δ_a Aileron deflection angle
- δ_r Rudder deflection angle
- $\delta_{at_{trim}}$ Additional aileron trim tab deflection angle required to trim
- $\delta_{rt_{trim}}$ Additional rudder trim tab deflection angle required to trim
- F_a Aileron stick (or wheel) force
- F_r Rudder pedal force

The remaining five variables not defined by the user are calculated and included in the output.

6.10.4 T.O. Rotation

The “T.O. Rotation” submodule can be used to determine the horizontal tail/v-tail/canard area and lift coefficient required for take-off rotation based on landing gear and center of gravity

locations as well as pitch attitude acceleration requirements.

6.10.5 Trimmed Lift (T from D)

This module is used for the determination of trimmed lift coefficients.

6.10.6 Trimmed Lift (T = Const)

This module can be used to calculate the trimmed lift coefficients on the canard, wing, horizontal tail and v-tail of an airplane at a given flight condition while accounting for flap effects. This module allows the user to quickly determine the trimmed condition of the airplane.

Before the **Trimmed Lift** submodules can be selected, the user must define one of five types of airplane configurations in the Airplane Configuration dialog box and trailing edge flap type in the Wing Configuration dialog box (See Section 2.2.3, Figure 2.16).

6.11 Stick Free Static Margin

In this module, the stick free static margin is calculated.

6.12 Stick Force

In this module, the stick force and the stick force speed gradient are calculated.

6.13 Aileron Force

In this module, the aileron wheel force is calculated.

6.14 Rudder Force

In this module, the rudder pedal force and the rudder pedal force gradient are calculated.

6.15 Wing Location

In this module the C.G. range and Static Margin are plotted as a function of the wing location allowing the user to quickly make a decision on the wing location, which would result in a desired Static Margin and a C.G. range

7 Dynamics Module

7.1 General Description

The purpose of the **Dynamics** module is to help the user analyze the open loop dynamic characteristics of the airplane in a given flight condition, and to help the user analyze single and double loop feedback control systems of the airplane. If the open loop dynamic characteristics of the airplane are known, the **Control** analysis submodule can be used to perform root locus analyses. The **Control** analysis can also be used to analyze a system open loop transfer function in the frequency domain. The methodology used to analyze open loop dynamic characteristics can be found in Reference 11. The methodology used to analyze feedback control systems can be found in Reference 12.

Use of the **Dynamics** module options will be described in the following sections.

7.2 Dynamics Main Window

After selecting the **Dynamics** module, the user can select from the two options displayed:

- **Dynamics** — For analyzing the airplane open loop dynamic characteristics for a given flight condition. The options provided in this module are discussed in Sections 7.3 through 7.5.
- **Control** — For analyzing feedback control systems. The options provided in this module are discussed in Sections 7.6 through 7.9.

Once the **Dynamics** module has been selected in the main window, a new menu appears with three submodules:

7.3	**Longitudinal**	For estimation of the longitudinal dynamic characteristics.
7.4	**Lateral-Direct.**	For estimation of the lateral-directional dynamic characteristics.
7.5	**Roll Coupling**	For the roll-pitch yaw coupling effect of the dynamic analysis.

Once the **Control** module has been selected in the main window, a new menu appears with four submodules:

7.7	**Root Locus (s)**	For analysis of a single and double loop feedback control system.
7.8	**Bode Method**	For development of an airplane frequency response Bode plot.
7.9	**Human Pilot**	For estimation of a human pilot transfer function.
7.10	**Erase T.F.**	For erasing one or all of the calculated transfer functions.

Section 7.6 presents the two methods used for defining transfer function and for loading data into the **Control** analysis module.

7.3 Longitudinal Dynamics

After selecting the **Longitudinal** option, the following options will be displayed:

7.3.1	**Transfer Function**	For transfer function computation.
7.3.2	**Flying Qualities**	For flying qualities checking.
7.3.3	**Sensitivity**	For longitudinal derivative sensitivity analysis.

7.3.1 Calculate Transfer Function

Transfer Function is used to calculate the longitudinal characteristic equations, associated modes (including frequencies and damping ratios) and the associated transfer functions. After choosing **Transfer Function**, the user is presented with the following options:

- **Stabilizer** For calculating the stabilizer open loop transfer function.
- **Elevator** For calculating the elevator open loop transfer function.
- **Canard** For calculating the canard open loop transfer function.
- **Canardvator** For calculating the canardvator open loop transfer function.
- **V-Tail** For calculating the v-tail open loop transfer function.
- **Ruddervator** For calculating the ruddervator open loop transfer function.
- **Flying Wing** For calculating the flying wing open loop transfer function.
- **Elevon** For calculating the elevon open loop transfer function.

- **None** For calculating the airplane modes without a control surface.

NOTE: The corresponding control surface must be defined by the user in the Control Surfaces Configuration dialog box before the dynamic analysis can be conducted.

After all input parameters are defined and the **Calculate** option is selected, the longitudinal transfer function output parameters will be displayed, and the transfer function will be shown in dialog boxes. When certain output variables such as time constants, damping ratios or frequencies cannot be calculated, the program leaves a blank in the appropriate output box. The transfer functions will be redisplayed when selecting the **Calculate** option. These transfer functions can be printed either directly from the dialog box or by selecting the **Print Parameters** options in the Print dialog box.

7.3.2 Longitudinal Flying Qualities

Flying Qualities performs a check on the calculated longitudinal modes against the relevant regulations. The flying qualities of the airplane are compared with the flying qualities as specified in the regulations chosen by the user in the Certification and Type dialog box. Where no specifications are available for FAR part 23 or FAR part 25, MIL-F-8785C specifications are used. If the user chooses MIL-Specs as the certification, one of the following options must be chosen:

- Land Based For land based airplanes
- Carrier Based For aircraft carrier based airplanes
- Land & Carrier For land and carrier based airplanes

After selecting the airplane certification type, the flight phase category must be defined in the Flight Condition Definition dialog box. The user has the following options:

- Flight Phase A Non-terminal flight phases that require rapid maneuvering, precision tracking or precise flight-path control.

- Flight Phase B — Non-terminal flight phases that are normally accomplished using gradual maneuvers and without precision tracking, although accurate flight-path control may be required.
- Flight Phase C — Terminal flight phases that are normally accomplished using gradual maneuvers and usually require accurate flight-path control.

The user also needs to define the airplane class from the following options in the Classification dialog box:

- Class I — Small, light airplanes
- Class II — Medium weight, low-to-medium maneuverability airplanes
- Class III — Large, heavy, low-to-medium maneuverability airplanes
- Class IV — High-maneuverability airplanes

Once the airplane certification type, airplane flight phase and airplane class have been selected, the input/output window for the longitudinal mode checking is displayed. In this submodule the user can compare the phugoid and short period mode with flying qualities as specified in MIL-F-8785C. After the input is defined, the output group will be filled. The output group displays data for the selected flight phase category. When the user selects an output parameter, information concerning that parameter can be accessed by selecting **Help** on the calculator.

Once the longitudinal mode checking has been performed, the user can get a plot of the short period frequency requirements as specified in MIL-F-8785C by selecting the **Plot** button. A description of the standard plot options can be found in Section 2.1.4 of Part II of this user's manual. The short period frequency characteristic of the current aircraft configuration is also plotted.

7.3.3 Longitudinal Stability Derivative Sensitivity Analysis

The **Sensitivity** option provides the capability to perform a sensitivity analysis for all longitudinal derivatives, weight and inertia parameters. The resulting sensitivity graphs show how different modes of an airplane may vary if one of the derivatives, weight or inertia parameters is varied.

Once the input parameters have been entered in the **Transfer Function** submodule, the user can enter the **Sensitivity** submodule.

The following sensitivity analysis options will be displayed:

- **Angle of Attack (α)** The parameters that can be varied are C_{D_α}, C_{L_α}, C_{m_α}, $C_{L_{\dot{\alpha}}}$, and $C_{m_{\dot{\alpha}}}$.
- **Pitch Rate (q)** The parameters that can be varied are C_{L_q} and C_{m_q}.
- **Speed (u)** The parameters that can be varied are C_{D_u}, C_{L_u}, and C_{m_u}.
- **Thrust (T)** The parameters that can be varied are, $C_{m_{T_u}}$, and $C_{m_{T_\alpha}}$, $C_{T_{x_u}}$.
- **Weight** The parameter that can be varied is $W_{current}$.
- **Inertia** The parameter that can be varied is I_{yy_B}.
- **Steady State** The parameters that can be varied are C_{D_1}, C_{L_1}, C_{m_1}, $C_{m_{T_1}}$, $C_{T_{x_1}}$, and U_1.

Once the user has selected one of the sensitivity analysis options, an input window will appear asking the user to define the lower and upper limit of the variable to be investigated. The sensitivity plot is displayed after these limits are defined and the **Plot** option is selected. The plot options are described in Section 2.1.4 of Part II of the manual. The input parameters required to perform a sensitivity analysis for the longitudinal derivatives can be entered in the **Transfer Function** submodule. The methodology used for the sensitivity analysis can be found in Section 6.4 of Reference 11.

7.4 Lateral-Directional Dynamics

After selecting the **Lateral-Direct.** option, the following options will be displayed:

7.4.1 **Transfer Function** For transfer function computation.

7.4.2 **Flying Qualities** For flying qualities checking.

7.4.3 **Sensitivity** For lateral-directional derivative sensitivity analysis.

7.4.1 Transfer Function

Transfer Function is used to calculate the lateral-directional characteristic equations, associated modes (including frequencies and damping ratios) and the associated transfer functions. After choosing **Transfer Function**, the user is presented with the following options:

- **Aileron** For calculating the aileron open loop transfer function.
- **Spoiler** For calculating the spoiler open loop transfer function.
- **Vert. Tail** For calculating the vertical tail open loop transfer function.
- **Rudder** For calculating the rudder open loop transfer function.
- **V-Tail** For calculating the v-tail open loop transfer function.
- **Ruddervator** For calculating the ruddervator open loop transfer function.
- **Spoileron** For calculating the spoileron open loop transfer function.

NOTE: The corresponding control surface must be defined by the user in the Control Surfaces Configuration dialog box before the dynamic analysis can be conducted.

After all input parameters are defined and the **Calculate** option is selected, the lateral-directional transfer function output parameters will be displayed, and the transfer function will be shown in dialog boxes. When certain output variables such as time constants, damping ratios or frequencies cannot be calculated, the program leaves a blank in the appropriate output box. The transfer functions will be redisplayed when selecting the **Calculate** option. These transfer functions can be printed either directly from the dialog box or by selecting the **Print Parameters** options in the Print dialog box.

7.4.2 Lateral-Directional Flying Qualities

Before invoking the **Flying Qualities** option, the user must select the aircraft certification category in the Certification and Type dialog box for which the flying qualities of the aircraft configuration are to be checked. For FAR 23 certified aircraft, the FAR 23.157 regulations are used for roll mode checking and MIL-F-8785C regulations are used for spiral and Dutch roll mode checking. Because the FAR 25 regulations do not have lateral-directional flying quality requirements, the MIL-F-8785C for land-based aircraft are used for FAR 25 certified aircraft. In

case of a MIL-F-8785C certified aircraft, the user selects the aircraft base:

- Land Based For land based airplanes
- Carrier Based For aircraft carrier based airplanes
- Land & Carrier Based For land and carrier based airplanes

The user also needs to define the airplane class from the following options in the Classification dialog box:

- Class I Small, light airplanes
- Class II Medium weight, low-to-medium maneuverability airplanes
- Class III Large, heavy, low-to-medium maneuverability airplanes
- Class IV High-maneuverability airplanes (only for MIL-F-8785C)

After selecting the airplane category, the flight phase category must be defined in the flight condition dialog box. The user has the following options:

- Flight Phase A Plot the requirements for non-terminal flight phases that require rapid maneuvering, precision tracking or precise flight-path control.
- Flight Phase B Plot the requirements for non-terminal flight phases that are normally accomplished using gradual maneuvers and without precision tracking, although accurate flight-path control may be required.
- Flight Phase C Plot the requirements for terminal flight phases that are normally accomplished using gradual maneuvers and usually require accurate flight-path control.

Once the aircraft certification category has been completely defined, the user can choose from the following two options:

7.4.2.1 **Roll Performance**

7.4.2.2 **Spiral, Dutch Roll**

7.4.2.1 Roll Performance

The Flying Qualities of the roll performance can be performed after selection of the **Roll Performance** option. After the input is defined, the output group will be filled.

7.4.2.2 Spiral and Dutch Roll

The Flying Qualities of the spiral and Dutch roll performance can be performed after selection of the **Spiral, Dutch Roll** option. After the inputs are defined, the output group will be filled. The selected flight phase category data are displayed in the output group. Once the lateral-directional Dutch roll mode checking has been performed, by selecting the **Plot** button, the user can plot the Dutch roll frequency and damping ratio requirements as specified in MIL-F-8785C. The current aircraft configuration Dutch roll characteristic is plotted in the same figure. A description of the standard plot options can be found in Chapter 2 of Part II of this user's manual.

7.4.3 Lateral-Directional Stability Derivative Sensitivity Analysis

The **Sensitivity** option provides the capability to perform a sensitivity analysis for all lateral-directional derivatives, weight and inertia parameters. The resulting sensitivity graphs show how different modes of an airplane may vary if one of the derivatives, weight or inertia parameters is varied.

Once the input parameters have been entered in the **Transfer Function** submodule, the user can enter the **Sensitivity** submodule. The following sensitivity analysis options will be displayed for the lateral-directional case:

- **Sideslip (β)** — The parameters that can be varied in this submodule are C_{y_β}, C_{l_β}, C_{n_β}, and C_{nT_β}.
- **Roll Rate (p)** — The parameters that can be varied in this submodule are C_{y_p}, C_{l_p}, and C_{n_p}.

- **Yaw Rate (r)** The parameters that can be varied in this submodule are C_{y_r}, C_{l_r}, and C_{n_r}.
- **Weight** The parameter that can be varied in this submodule is $W_{current}$.
- **Inertias** The parameters that can be varied in this submodule are I_{xx_B}, I_{yy_B} and I_{zz_B}.
- **Steady State** The parameter that can be varied in this submodule is U_1.

Once the user has selected one of the sensitivity analysis options, an input/output window will appear asking the user to define the lower and upper limit of the variable to be investigated. The sensitivity plot is displayed after these limits are defined and the **Plot** option is selected. The plot options are described in Chapter 2 of Part II of the manual. The input parameters required to perform a sensitivity analysis for the lateral-directional derivatives can be entered in the **Transfer Function** submodule. The methodology used for the sensitivity analysis can be found in Section 6.4 of Reference 11.

7.5 Roll Rate Coupling Analysis

The purpose of the roll rate-coupling submodule is to analyze the roll-pitch-yaw coupling effect. This allows the designer to determine whether or not the aircraft will be stable during steady roll, and to adjust the level of longitudinal and/or lateral-directional stability if needed. Once the **Roll Coupling** option is selected, an input/output window appears showing the roll-pitch-yaw coupling parameters. This option is used to calculate the parameters associated with the critical roll rate. After the **Calculate** option has been selected, the user may see a roll rate-coupling plot by selecting the **Plot** option. The range of the variable to be investigated may be entered in the input parameter list. The plot displays the current configuration along with symbols marking the points of steady state roll rate, yaw divergence and pitch divergence.

7.6 Defining Control Transfer Functions

After selecting the **Control** option, the user is presented with the various windows for control systems described in Sections 7.7 and 7.8. Once a control system is displayed, the user may select any combination (or all) of the eight transfer function boxes, as needed. Should the user choose not to use all the available T.F. boxes, the transfer functions in the unused boxes will default to a unity transfer function. The user may execute the **Control** analysis module with the control loop system containing:

- Standard airplane transfer functions.
- User-defined transfer functions.
- A combination of both standard airplane and user-defined transfer functions.

Once a T.F. box is selected, a list is displayed allowing the user to select the desired transfer function. The transfer function options presented in this list are:

- Elevator--Speed For the Speed-to-Elevator Transfer Function.
- Elevator--Angle of Attack For the Angle-of-Attack-to-Elevator Transfer Function.
- Elevator--Pitch Angle For the Pitch-Angle-to-Elevator Transfer Function.
- Stabilizer--Speed For the Speed-to-Stabilizer Transfer Function.
- Stabilizer--Angle of Attack For the Angle-of-Attack-to-Stabilizer Transfer Function.
- Stabilizer--Pitch Angle For the Pitch-Angle-to-Stabilizer Transfer Function.
- Canardvator--Speed For the Speed-to-Canardvator Transfer Function.
- Canardvator--Angle of Attack For the Angle-of-Attack-to-Canardvator Transfer Function.
- Canardvator--Pitch Angle For the Pitch-Angle-to-Canardvator Transfer Function.
- Canard--Speed For the Speed-to-Canard Transfer Function.
- Canard--Angle of Attack For the Angle-of-Attack-to-Canard Transfer Function.
- Canard--Pitch Angle For the Pitch-Angle-to-Canard Transfer Function.
- V-Tail—Speed For the Speed-to-V-Tail Transfer Function.
- V-Tail--Angle of Attack For the Angle-of-Attack-to-V-Tail Transfer Function.
- V-Tail--Pitch Angle For the Pitch-Angle-to-V-Tail Transfer Function.
- Ruddervator—Speed For the Speed-to-Ruddervator Transfer Function.

- Ruddervator--Angle of Attack For the Angle-of-Attack-to-Ruddervator Transfer Function.
- Ruddervator--Pitch Angle For the Pitch-Angle-to-Ruddervator Transfer Function.
- Ruddervator--Sideslip Angle For the Sideslip-Angle-to-Ruddervator Transfer Function.
- Ruddervator--Bank Angle For the Bank-Angle-to-Ruddervator Transfer Function.
- Ruddervator--Heading Angle For the Heading-Angle-to-Ruddervator Transfer Function.
- Flying Wing--Speed For the Speed-to-Elevator Transfer Function.
- Flying Wing --Angle of Attack For the Angle-of-Attack-to-Elevator Transfer Function.
- Flying Wing --Pitch Angle For the Pitch-Angle-to-Elevator Transfer Function.
- Elevon--Speed For the Speed-to-Stabilizer Transfer Function.
- Elevon --Angle of Attack For the Angle-of-Attack-to-Stabilizer Transfer Function.
- Elevon --Pitch Angle For the Pitch-Angle-to-Stabilizer Transfer Function.
- Aileron--Sideslip Angle For the Sideslip-Angle-to-Aileron Transfer Function.
- Aileron--Bank Angle For the Bank-Angle-to-Aileron Transfer Function.
- Aileron--Heading Angle For the Heading-Angle-to-Aileron Transfer Function.
- Rudder--Sideslip Angle For the Sideslip-Angle-to-Rudder Transfer Function.
- Rudder--Bank Angle For the Bank-Angle-to-Rudder Transfer Function.
- Rudder--Heading Angle For the Heading-Angle-to-Rudder Transfer Function.
- Human Pilot For the Human Pilot Transfer Function.
- Time Delay For the Time Delay Transfer Function.
- User Defined For a Transfer Function defined by the user.

The transfer functions can be selected from the standard airplane transfer functions or defined by the user. If the longitudinal and lateral-directional stability derivatives of the airplane are known, the user may use the Dynamics module prior to using the Control analysis module to generate the longitudinal and lateral-directional dynamic transfer functions of the airplane. These transfer functions are transferred into the Control analysis module, and can only be generated in the Dynamics module.

The User Defined option allows the user to define a desired transfer function. An example of when this option might be used is if the user wishes to insert a filter into the feedback system.

The user would select the User Defined option to input the filter transfer function. The required transfer functions must be defined in the input/output window that appears.

The procedure for entering a transfer function into a Control loop is presented in the following steps:

1) Select the desired transfer function from the presented list and the numerator and denominator polynomial input window will appear on the screen. Boxes A_0 - A_6 are the coefficients of the numerator polynomial and boxes B_0 - B_6 are the coefficients of the denominator polynomial for respective powers of s. The polynomial may have a maximum degree of six. The A and B coefficients are extracted from the database if the user selected one of the standard airplane transfer function options 1 - 9. If the user selected the User Defined option, the A and B coefficients must be entered as input by the user.
2) If the user wishes to change a user-defined transfer function, which has already been defined in a T.F. box, the User Defined option must be selected after which the polynomial coefficients can be changed. This procedure will load the new transfer function into the program database replacing the existing one.
3) If the user wishes to transform an airplane transfer function in terms of an angle (for example, roll-angle-to-aileron transfer function) to a transfer function in terms of rate (for example, roll-rate-to-aileron transfer function), the angle transfer function can be multiplied by S (which the user can input in another T.F. box on the same path) to convert to a rate transfer function. Similarly, a rate transfer function can be converted to an angle transfer function by multiplying the rate transfer function by (1/S).

7.7 S-Plane Root Locus Analysis

Using the **Root Locus(s)** submodule, the user can generate a root locus plot, in the S-plane, for continuous systems. This submodule consists of the following five options:

7.7.1	**Single Loop**	For single loop feedback control systems.
7.7.1	**Double Loop K:fwp**	For double loop control systems with the inner loop gain in the forward path.
7.7.1	**Double Loop K:fbp**	For double loop control systems with the inner loop gain in the feedback path.
7.7.2	**Gyro Tilt**	To analyze the gyro tilt angle effect.

7.7.1 S-Plane Single and Double Loop Analysis

After selecting a single or double control loop analysis and defining all required transfer functions (see Section 7.6), the **Plot Open Loop** button is selected to calculate the root locus of the control loop. An input/output window will be displayed in which the lower and upper limit for the system gain, the lower and upper limit for damping ratio lines, the lower and upper limit for natural frequency arcs, the number of gain points, the number of damping ratio lines, the number of natural frequency arcs and the design gain can be specified. In a double loop control system, the user is also asked to define the inner loop gain. If the user only wishes to see the root locus plot for a range of system gains, the design gain, number of damping ratio lines and number of natural frequency arcs may be left undefined. If the design gain is defined it is displayed in the root locus plot. After selection of the Plot option, the root locus plot is displayed. A detailed explanation of the plot options can be found in Chapter 2 of Part II of the user's manual.

7.7.2 S-Plane Gyro Tilt Analysis

An important consideration in the analysis of single loop control systems is the study of gyro tilt angle effect. This study is essential in the design of yaw dampers. After selecting the **Gyro Tilt** submodule, the gyro tilt angle analysis window appears. This new window consists of six separate transfer function (T.F.) boxes in addition to the **Plot Open Loop** button. The required transfer functions must be defined by methods described in Section 7.6.

It should be noted that there are additional constraints when defining transfer functions in the

Gyro Tilt submodule, which are described below:

1) For gyro tilt analysis, the inner loop is not a feedback loop. To analyze the gyro tilt effect, the yaw rate and roll rate transfer functions must be defined in the inner loop.
2) In addition, the yaw-rate-to-rudder transfer function must be defined in T.F. box 5 and the roll-rate-to-rudder transfer function must be defined in T.F. box 7 according to **Gyro Tilt** analysis theory (see Section 13.1.1.2 of Reference 12).
3) Yaw-rate-to-rudder and roll-rate-to-rudder are not part of the standard airplane transfer functions and must be defined using the **User Defined** option (see Section 7.6 of the user's manual).

After all the required transfer functions have been defined, the **Plot Open Loop** button is selected to calculate the root locus of the control loop. A new input menu will appear on the screen, asking the user to specify the steady state angle of attack plus the angle between the gyro sensitive axis and the Z-axis of the body system, $(\alpha + \alpha_r)$. In addition, the user is asked to define the lower and upper limits for the system gain, damping ratio and natural frequency, the number of gain, damping ratio and natural frequency points, and the design gain. If desired, the design gain, number of damping ratio points and number of natural frequency points may be left undefined. After selection of the **Plot** option, the root locus figure will be displayed. A detailed explanation of the plot options can be found in Chapter 2 in Part II of the user's manual.

7.8 Bode Method

The function of the Bode analysis submodule is to develop a frequency response of an airplane in the form of a Bode plot. On a Bode plot, the frequency is plotted as the logarithm of frequency and the amplitude is plotted as twenty times the logarithm of the amplitude ratio, or decibels (see Section 11.4 of Reference 12). After selecting the **Bode Method** option, the single feedback loop control system window appears. This new window consists of eight separate transfer function (T.F.) boxes in addition to the **Plot Open Loop** button. After all the required transfer functions have been defined, the **Plot Open Loop** button is selected to calculate the open loop dynamic characteristics of the control system. After the user defines a frequency range, the **Plot** button is used to generate the Bode plot. A detailed explanation of the plot options can be found in

Chapter 2 in Part II of the user's manual.

7.9 Human Pilot

The Human Pilot calculation can be used to estimate a human pilot transfer function for use in the open loop control system analysis. The Human Pilot module can be used to model pilots of differing abilities, reaction times and physical fitness. This module can even be used to show the dangers of a drunken pilot in the loop. The methodology used to analyze a human pilot transfer function can be found in Chapter 10 of Reference 12.

7.10 Time Delay

The Time Delay calculation can be used to account for time delays and bus transmission delays due to flight control computer systems.

7.11 Erase T.F.

The user should be aware that the program database is structured so that the transfer functions, which are loaded into the T.F. boxes, will be passed from one control analysis option to another. That is, if the user has defined transfer functions in T.F. boxes 1 and 3 in the single loop root locus option, these same transfer functions will remain in T.F. boxes 1 and 3 should the user quit the single loop option and execute the double loop, gyro tilt analysis, or Bode method option. This saves the user from having to define these same transfer functions again should the need arise to use another root locus option. If the user does not wish to pass the transfer functions defined in one control system to another, the **Erase T. F.** button may be used. This option initializes all the user-defined transfer functions to a unity transfer function.

In addition to using the **Erase T. F.** button, the transfer function can also be deleted by right clicking on each T.F. box and selecting **Erase T. F.**

8 Loads Module

8.1 General Description

The purpose of this module is to estimate loads placed on airplane components and to determine important information for structural design and sizing. The **Loads** module consists of two submodules: **V-n Diagram** and **Structural Loads**. The purpose of the **V-n Diagram** submodule is to determine load factors and their corresponding speeds. These methods are based on Section 4.2 of Reference 5. The purpose of the **Structural Loads** submodule is to calculate the internal forces and moments in the structural components of an airplane. Use of the **Loads** module options will be described in the following sections.

8.2 Loads Main Window

After invoking the **Loads** module, the user may enter the following modules:

- **V-n Diagram** — In this submodule, velocity vs. load factor (V-n) diagrams can be constructed for the following types of airplanes: FAR 23 certified, FAR 25 certified and MIL-A-8861 (ASG) certified airplanes (Reference 17). The options presented in this module are discussed in Section 8.3.
- **Structural** — In this submodule the total internal loads for each structural component can be calculated in any combination that the user desires. The options presented in this module are discussed in Section 8.4.

8.3 V-n Diagram

Before invoking **V-n Diagram**, the user must choose one of three certification options from the Certification and Type dialog box.

The options are as follows:

- FAR 23 — V-n diagrams can be constructed for FAR 23 certified airplanes. After selecting FAR 23 in the certification dialog box, a selection between the following FAR 23 airplane categories must be made:
  - NORMAL
  - UTILITY
  - ACROBATIC
- FAR 25 — V-n diagrams can be constructed for FAR 25 certified airplanes.
- MIL-A-8861 (ASG) — V-n diagrams can be constructed for military certified airplanes according to the MIL-8861 (ASG) regulations (Reference 17).

The V-n diagram output parameters are generated after all input data are provided and the **Calculate** option is selected. Once the V-n diagram input and output parameters are defined in the V-n Input window, the user can use the **Plot** option. A detailed description of the standard plot options is described in Section 2.1.4 of Part II of the manual.

8.4 Structural Loads

After invoking the **Structural** button the following options will be available to calculate the loads acting on a structural component:

8.4.1 **Fuselage** — For estimation of the structural loads on the fuselage.

8.4.1 **Wing** — For estimation of the structural loads on the wing.

8.4.1 **Horizontal Tail** — For estimation of the structural loads on the horizontal tail.

8.4.1 **Canard** — For estimation of the structural loads on the canard.

8.4.1 **Vertical Tail** — For estimation of the structural loads on the vertical tail.

8.4.1 **V-Tail** — For estimation of the structural loads on the v-tail.

8.4.2 **Load Factors** — For estimation of the accelerations and rates acting on the airplane. Before the total internal loads for any structural component can be calculated, the linear accelerations, angular accelerations and angular rates must be calculated using this option.

8.4.1 Fuselage/Wing/Horizontal Tail/Canard/Vertical Tail/V-Tail

When the **Fuselage**, **Wing**, **Horizontal Tail**, **Canard**, or **Vertical Tail** option is chosen the following options will be available for calculation of the respective structural component loads:

- **Conc. Weights** — For calculation of loads due to a mass placed at one concentrated point on the structural component (Section 8.4.1.1).
- **Dist. Weights** — For calculation of loads due to a mass that is distributed over the structural component (Section 8.4.1.2).
- **User Loads** — For calculation of user specified loads acting on a structural component (Section 8.4.1.3). Used for the fuselage only.
- **Aerodynamic** — For calculation of the aerodynamic loads acting on a structural component (Section 8.4.1.3). Used for all components except fuselage.
- **Load Stations** — For calculation of the load stations used for each structural component (Section 8.4.1.4).
- **Gear/Engine/Misc** — For calculation of the loads that result from landing gear, engine or miscellaneous reactions (Section 8.4.1.5).
- **Total Internal** — For calculation of the total internal loads acting on the structural component (Section 8.4.1.6).

Different concentrated, distributed, user, aerodynamic, landing gear, engine or miscellaneous loads can be defined for each of the structural components.

8.4.1.1 Concentrated Weights

The Concentrated Weights module is used to define the weight and location of masses acting at concentrated positions on a structural component. When **Conc. Weights** is selected the following options will appear:

8.4.1.1.1 **Add Component**

8.4.1.1.2 **Select Compon.**

8.4.1.1.3 **Copy Table**

8.4.1.1.4 **Conc. Weights**

8.4.1.1.1 Add Concentrated Weight Component

This option is used to define weight components other than those found in the weight and balance tables of the **Weight** module (see Chapter 1). The number of new objects is chosen, and then the name, weight and center of gravity positions can be entered for each mass.

8.4.1.1.2 Select Concentrated Weight Component

This option is used to select components to be used as a concentrated weight to act on the structural component. The dialog box contains all of the weight items used in the weight and balance tables of the **Weight** module (see Chapter 1). Components that are defined using the **Add Component** option (subsection 8.4.1.1.1) can be found in the **User Defined** category. The user can select objects by using the mouse button and then dragging down until all desired objects are highlighted. When the **>> Add** button is pressed the objects will be added to the Current Selection list. To remove objects from the list repeat the same procedure using the Current Selection list and then clicking the **Remove <<** button.

8.4.1.1.3 Copy Concentrated Weight Table

This option is used to copy a concentrated weight table from another flight condition. A list of all of the flight conditions will be displayed. By choosing one of the flight conditions, all of the items in the Current Selection list from that flight condition will replace all of those in the current flight condition.

8.4.1.1.4 Concentrated Weights

This option is used to show a list of the selected concentrated weights and the corresponding center of gravity locations. If the weight and center of gravity data have not already been entered into the **Center of Gravity** submodule in **Weight** (Chapter 1) then they should be entered here. This data will be used to calculate the internal loads due to concentrated weights in the **Total Internal** loads module.

8.4.1.2 Distributed Weights

The Distributed Weights module is used to define the location and weight of masses that are distributed over the structural component. The following options will be available when **Dist. Weights** is selected:

8.4.1.2.1 **Add Component**

8.4.1.2.2 **Select Compon.**

8.4.1.2.3 **Copy Table**

8.4.1.2.4 **Dist. Weights**

8.4.1.2.1 Add Distributed Weight Component

This option is used to define weight components other than those found in the weight and balance tables of the **Weight** module (see Chapter 1). The number of new objects is chosen, and then the name, weight and center of gravity positions can be entered for each mass.

8.4.1.2.2 Select Distributed Weight Component

This option is used to select components to be used as a distributed weight to act on the structural component. The dialog box contains all of the weight items used in the weight and balance tables of the **Weight** module (see Chapter 1). Components that are defined using the **Add Component** option (subsection 8.4.1.1.1) can be found in the **User Defined** category. The user can select objects by using the mouse button and then dragging down until all desired objects are highlighted. When the **>> Add** button is pressed the objects will be added to the Current Selection list. To remove objects from the list repeat the same procedure using the Current Selection list and then clicking the **Remove <<** button.

8.4.1.2.3 Copy Distributed Weight Table

This option is used to copy a distributed weight table from another flight condition. A list of all of the flight conditions will be displayed. By choosing one of the flight conditions all of the items in the Current Selection list from that flight condition will replace all of those in the current flight condition.

8.4.1.2.4 Distributed Weights

This option is provided to calculate and display the distributed weights from masses chosen in the **Select Compon.** option. There are two choices in this section:

- W_i, S_{cg} — If the distributed weights have been defined in the **Weight** module (Chapter 1), those definitions will appear in the distributed weights table and the program will distribute the weight over the entire structural component to result in the specified center of gravity. If this method is used the program will ignore the beginning and ending locations and weights per unit length.
- W/L, S_1, S_2 — If the beginning and ending locations and weights per unit length are defined, the program assumes that the weight per unit length varies linearly from the beginning location to the end location.

Fuselage distributed weights are assumed to be located along the centerline. When the **Calculate** button is selected, the program will check the input of the distributed weight. The program checks whether the distributed weight input is defined completely and logically. If there are any errors, the program will display a message indicating what the error is. The program will check both **Dist. Weights** options. The distributed weights table is flight condition dependent, and will be reset for each new flight condition. The internal loads generated by each of the distributed weights selected can be calculated in the **Total Internal** loads module using the data contained in the distributed weights table.

8.4.1.3 User/Aerodynamic Loads

Any aerodynamic, control surface, flap, or user defined loads acting on structural components can be defined in the **Aerodynamic** module for the wing, horizontal tail, canard or vertical tail. For the fuselage, user defined loads can be defined in the **User Loads** module. The following options are available when selected:

- **Steady State** — (Aerodynamic only) The steady state aerodynamic loads acting on each lifting surface are defined separately as lift, drag, and pitching

moment. They can be defined in the **Lift** module, **Drag** module, and the **Moment** module (Chapter 2).

- **Control/Flap Defl.** (Aerodynamic only) Control surface and flap deflection loads can be defined as changes in the surface coefficients or as dimensional forces and moments. The **Coefficients** module is used to define the change in coefficients of the surface created by the control surface deflection. It is also used to calculate dimensional loads from the coefficients. The **Forces** module and **Moments** module can be used to directly define the dimensional loads created by a control surface deflection.
- **Concentrated** The **Concentrated** module can be used to define any loads acting on the fuselage or lifting surfaces as pure concentrated forces or moments. These forces and moments may be defined in terms of changes in the coefficients of the surface in the **Concentrated Coefficients** (Aerodynamic only). Forces may be defined in the **Concentrated Forces** module. Moments may be defined in the **Concentrated Moments** module.
- **Distributed** The **Distributed** module can be used to define any loads acting on the fuselage or lifting surfaces as pure distributed forces or moments. These forces and moments may be defined in terms of changes in the coefficients of the surface in the **Distributed Coefficients** (Aerodynamic only). Forces may be defined in the **Distributed Forces** module. Moments may be defined in the **Distributed Moments** module.

8.4.1.4 Load Stations

Before the **Total Internal** loads module may be accessed, the load stations of the structural component must be defined. The internal loads will be calculated at each of the load stations in the **Total Internal** module. The load stations module simply divides the span of the surface (or length of the fuselage) into equal segments. The location of each load station is displayed in the

load station table. All load stations are defined in the weight and balance axis system. For horizontal surfaces, the load station locations are defined in the Y direction to represent spanwise locations. Vertical tail load stations are defined in the Z direction to represent spanwise locations. Fuselage load stations are defined along the length of the fuselage in the X direction. The number of load stations may be selected in the input parameter list, with a maximum of 21 load stations. The location of each load station may be changed in the load station table, with the exception of the first. The location of the first load station must be zero, and the location of the last load station may not be larger than the span of the surface (or length of the fuselage). All other loads stations must be in sequential order.

8.4.1.5 Gear/Engine/Misc

The **Gear/Engine/Misc** module can be used to define any landing gear reactions, engine thrust forces, or miscellaneous loads not defined elsewhere. These reactions can be specified outside of the structural component. These are similar to the **Concentrated Forces** and **Concentrated Moments** defined in the **User Loads** and **Aerodynamic Loads** modules. The structural component onto which each **Gear/Engine/Misc** load acts must be chosen. The locations of these loads are defined by coordinates in the weight and balance axis system. This module is flight condition dependent and will be reset for each flight condition.

8.4.1.6 Total Internal

The **Total Internal** loads module calculates all forces and moments acting on the structural component at each of the load stations defined in the **Load Stations** module. All external loads selected to act on the structural component must be defined in the **Conc. Weights**, **Dist. Weights**, **Aerodynamic**, **User Loads** or **Gear/Engine/Misc** loads modules. **Total Internal** loads must have already been calculated for all surfaces for which surface reactions have been selected. The internal loads are calculated in the Libove Coordinate System. Horizontal surfaces are split into right and left halves. The **Total Internal** loads table is flight condition dependent, and will be reset for each new flight condition.

8.4.2 Load Factors

The accelerations acting on the aircraft structure are found by solving the airplane equations of motion. The kinematic and force equations in the airplane stability axis system are solved for the airplane linear accelerations, angular rates, and angular accelerations in the body fixed axis system. By solving the angular rate and angular acceleration equations first, the force equations can then be solved for the linear accelerations. This module must be completed before **Total Internal** loads can be calculated for any structural component.

9 Structures Module

9.1 General Description

The purpose of this module is to estimate the size and weight of the structural components. This is done using material properties and the results of the calculation of the **Total Internal** loads for the component (see Chapter 8). Use of the **Structures** module will be described in the following sections.

9.2 Structures Main Menu

After selecting the Structures module, the user can select from the two options displayed:

- **User Materials –** In this submodule, material properties that are not listed in the Available Materials table may be added and have their characteristics defined. These materials will be added to the User Defined category of the Available Materials table.

- **Class I -** In this submodule the weight and size of a structural component can be estimated. This submodule is explained in Section 9.2.1.

9.2.1 Class I Structures

This module is used to calculate the size and weight of a structural component to withstand the loads calculated in the **Loads** module based on the characteristics of the materials used. Before these calculations can be done the component must be defined in the Airplane Configuration dialog box, the **Total Internal** loads must be calculated and the structure of the lifting surfaces must be defined.

The structure for the fuselage does not need to be defined and the structure for a lifting surface is defined in Lifting Surface Cross-Section Structure dialog box, which has the following options:

- Single-Spar Semimonocoque
- Two-Spar Semimonocoque
- Two-Spar Drag Truss
- Single-Spar Circular
- Single-Spar Box

When a structural component is selected, the following options will become available:

- **Comp. Materials** — To select the materials used for different parts of the component. The Component Material Properties must be defined before **Weight Estimate** can be performed. When the Material Name column is selected for a section of a component, the Available Materials table dialog is displayed.
- **Section Properties** — To calculate the effective width and height of the structure at each load station by entering spar and surface locations. The effective width and height are calculated differently for the different types of structures. For the fuselage, the structure type must be defined at each load station.
- **Weight Estimate** — To size the component structure to the loads calculated in the **Loads** module (Chapter 8). The **Class I** method calculates an effective width and effective height of the structure at each load station and sizes the structural materials to withstand the loads.

10 Cost Analysis Module

10.1 General Description

The purpose of this module is to estimate various costs of airplane design programs. The estimation methods are presented in such a manner that they can be applied to civil and military airplanes of all types. The various cost definitions and cost estimation methods used for this module are as discussed in Chapter 1 through 7 of Reference 9. Use of the **Cost** module options will be described in the following sections.

10.2 Cost Main Window

After invoking the **Cost** button, seven options are displayed:

- **AMPR Weight** — For estimation of the Aeronautical Manufacturers Planning Report (AMPR) weight, which is defined on page 25 of Reference 9. This weight parameter is needed for estimation of the various costs in an airplane program. The options provided in this module are discussed in Section 10.3.
- **R.D.T.E. Cost** — For estimation of the research, development, test and evaluation cost. The options provided in this module are discussed in Section 10.4.
- **Prototype Cost** — For estimation of the cost of development, manufacturing and flight-testing of the prototypes. This submodule is to be used only for those airplane programs that are not intended for eventual production. The options provided in this module are discussed in Section 10.5.
- **Acquisition Cost** — For estimation of the manufacturing and acquisition costs. The difference between these costs is the profit made by the manufacturer. The options provided in this module are discussed in Section 10.6.

- **Operating Cost** (military) For estimation of the military airplane operating costs. The options provided in this module are discussed in Section 10.7.
- **Operating Cost** (civil) For estimation of the civil airplane operating costs. The options provided in this module are discussed in Section 10.8.
- **Life Cycle Cost** For estimation of the life cycle cost of an airplane program. The life cycle cost is defined as the sum of R.D.T.E. cost, acquisition cost, operating cost and disposal cost. The options provided in this module are discussed in Section 10.9.
- **Price Data** For estimation of the engine price, propeller price and airplane price as well as a rapid method for estimating prices of future designs. The options provided in this module are discussed in Section 10.10.

10.3 AMPR Weight

After invoking the **AMPR Weight** button, the user is presented with two options:

- **Detailed** Application of this method requires a detailed knowledge of the airplane component weights.
- **Alternate** In case detailed data of the airplane component weights is lacking, this submodule estimates the AMPR weight for a given take-off weight.

10.4 R.D.T.E. Cost

Selecting the **R.D.T.E. Cost** button will display the following five options:

- **Engr. & Design** For estimation of the airframe engineering and design cost.
- **Dev. Sup. & Test** For estimation of the development support and testing cost.
- **Test Airplanes** For estimation of the flight-test airplanes cost.
- **Test Operations** For estimation of the flight-test operation cost.
- **Total Cost** For estimation of the total R.D.T.E. cost, the test and simulation facilities cost, the R.D.T.E. profit, and the cost to finance the R.T.D.E. phases.

10.5 Prototype Cost

The function of this option is to estimate the cost of development, manufacturing and flight-testing of prototype airplanes. This submodule is to be used only for those airplane programs that are not aimed at eventual mass production. Estimation of the prototype cost should be applied only to prototype programs where 1-4 airplanes are constructed. If more than 4 prototypes are to be constructed, the **R.D.T.E. Cost** option should be used for calculation of the prototype cost.

10.6 Acquisition Cost

After invoking the **Acquisition Cost** button, a menu is displayed with the following four options:

- **Engr. & Design** For estimation of the airframe engineering and design cost.
- **Prog. Production** For estimation of the airplane program production cost.
- **Test Operations** For estimation of program production flight-test operations cost.
- **Total Cost** For estimation of the total acquisition cost, the cost to finance the manufacturing phase, and the profit.

10.7 Operating Cost for Military Airplanes

Before selecting the **Operating Cost** button, the user must specify the airplane civil/military designation. For military aircraft, a menu is displayed for estimating the operating cost of military airplanes in peacetime. The menu shows the following options:

- **Fuel, Oil, & Lub.** For estimation of the program cost of fuel, oil and lubricants.
- **Dir. Personnel** For estimation of the program cost of direct personnel.
- **Consum. Mat.** For estimation of the program cost of consumable materials.
- **Total Operation** For estimation of the total program operating cost.

10.8 Operating Cost for Civil Airplanes

Before selecting the **Operating Cost** button, the user must specify the airplane civil/military designation. For civil aircraft, a menu is displayed for estimating the operating cost of commercial airplanes.

The menu has the following options:

10.8.1 **Block Data** — For estimation of the time, speed, and distances corresponding to the mission from the point of beginning taxi before take-off to ending taxi after landing.

10.8.2 **Direct** — For estimation of direct operating cost.

10.8.3 **Indirect** — For estimation of indirect operating cost.

10.8.4 **Program** — For estimation of total program operating cost.

10.8.1 Block Data

All the parameters needed for operating cost estimation can be calculated in the **Block Data** input/output window. After invoking the **Block Data** switch, two options are displayed:

- **Time & Speed** — For calculating speed, range and time parameters used in the operating cost estimation method.
- **Utilization** — In this submodule, the annual utilization and total annual block distance can be calculated.

10.8.2 Direct Operating Cost

In the **Direct Operating** submodule, the user can estimate the direct operating cost, DOC, in US$/nm incurred while operating commercial airplanes. After selecting the **Direct Operating** button, five options are displayed:

- **Flying** — Select this option for estimation of the direct operating cost of flying. After invoking the **Flying** button, a menu appears with the following options:
  - **O Crew** — For estimating crew operating cost.
  - **O Fuel & Oil** — For estimating fuel and oil cost.
  - **O Insurance** — For estimating insurance cost.

- **O Total** For estimating the total flying cost.

- **Maintenance** Select this option for estimation of the direct operating cost of maintenance.

  Before selecting the **Maintenance** option, the user must specify the type of engine in the engine dialog box from the following options:

  O Jet Engine
  O Piston Engine
  O Propfan
  O Turboprop

  Once the engine type is selected, an input/output window is displayed.

- **Depreciation** Select this option for estimation of the direct operating cost of depreciation.

- **Fees** Select this option for estimation of the direct operating costs of landing fees, navigation fees and registry taxes.

- **Total** Select this option for estimation of the total direct operating cost.

10.8.3 Indirect Operating Cost

In this submodule the indirect operating cost can be estimated. After invoking the **Indirect** operating cost, two options are displayed:

- **Detailed** The indirect operating cost is a summation of the individual components.

- **Alternate** Because the airplane designer has very little influence over this cost category, the indirect operating cost is expressed as a fraction of the direct operating cost. For this method the user need only define the fraction parameter and the direct operating cost.

10.8.4 Program Operating Cost

After invoking the Program option, the total program operating cost can be estimated.

10.9 Life Cycle Cost

The assumption is made that the R.T.D.E., program acquisition and program operating cost are estimated before entering this menu, therefore the only input parameter needed to estimate the life cycle cost is the program disposal cost. Program disposal cost is entered as a fraction of life cycle cost. It is also possible in this window to redefine the other **Life Cycle Cost** components.

10.10 Price Data

After the selection of the **Price Data** option, a menu is displayed with the following options:

- **Airplane** Before invoking the **Airplane** option, a type of airplane must be defined in the certification dialog box. The airplane price can be calculated after selecting the airplane category. The airplane cost for a certain calendar year can be estimated in US$.
- **Engine** Before selecting this option, the user must specify the engine type in the engine dialog box from the following options:
  - Jet Engine
  - Piston Engine
  - Propfan
  - Turboprop

  After the engine type selection is made, the engine price can be calculated.
- **Propeller** Before selecting this option, an engine other than a jet must be defined, and the propeller type must be chosen in the engine dialog box from these options:
  - Composite to calculate the composite propeller price.
  - Metal to calculate the metal propeller price.

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NOTE:

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